Subject: FW: Small Claims Patent Court Comments

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From: Robert Schmidt

To: ACUS Information, Kazia Nowacki

CC: Jere Glover, Alec Orban, Kevin Burns, Todd McCracken [redacted], Jody Milanese [redacted]

Attachments: image001.png, image004.jpg, image007.jpg, Federal Reserve Bank of Cleveland 2005 Annual Report, Patents #1 Indicator of Regional Wealth, page 17.pdf, Patents Number 1 Indicator of Regional Wealth Cleveland Federal Reserve Bank Working Paper 06-06.pdf, patenting-prosperity-rothwell $4,300 per worker.pdf

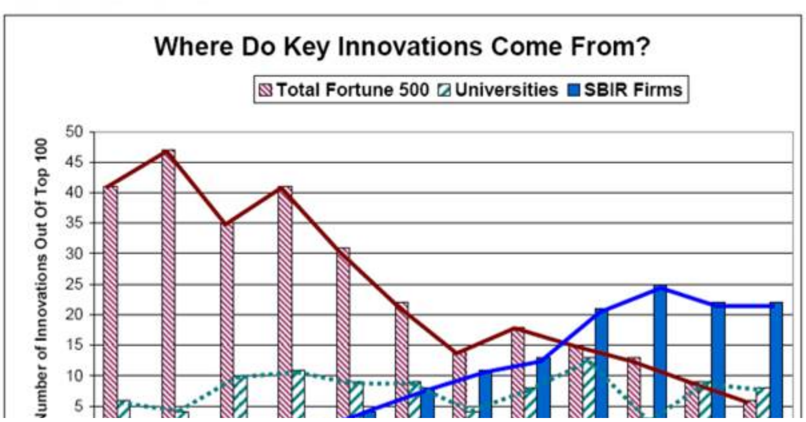
To the Administrative Conference:

The Small Business Technology Council writes to you to encourage the initiation of a small claims patent court for claims up to $5-10 million. Even more important, we suggest that new Article III patent courts be formed similar to bankruptcy courts. This will streamline the process and allow specialization, lowering cost and increasing speed to a just resolution of patent claims.

The Small Business Technology Council ("SBTC") is a non-partisan, non-profit industry association of companies dedicated to promoting the creation and growth of research-intensive, technology-based U.S. small business. To this aim, SBTC is involved in educational activities for small businesses, government officials, and officials of large companies. Through these activities, SBTC encourages the exchange of ideas and information to help transition research and development and technology into the commercial marketplace, and its mission is to ensure that the technology industry remains an inviting place for small businesses.

SBTC is a council of the National Small Business Association ("NSBA") which is the nation's oldest national small business advocacy association. With thousands of organizational and small business members in all fifty states, NSBA addresses the small-business community's primary public policy concerns on a nonpartisan basis. Because patents and the enforcement of patents are of great economic importance to the innovative small businesses that own them, the SBTC has a significant interest in prompt patent enforcement resolution. SBTC advocates for the 6,000 highly inventive firms that participate in the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs.

In many years, the SBIR firms produce more patents than all the universities combined, and they are more valuable patents. SBIR firms win more R&D 100 awards than all of the universities and more than Fortune 500 firms.



The US is continuing its decline in inventing and commercialization. America is now third in receiving Intellectual property payments, behind Ireland and The Netherlands.[i] Even worse, on a per capita basis, the US is currently 11th, behind Switzerland, Sweden, the United Kingdom, Hungary, Australia, and Israel. This is in part due to our weakened patent system. Of most importance, **America is number 11 in Bloomberg's Innovation Index (behind South Korea, and Finland)**.[ii]

If we are going to change these disturbing trends and have America regain the world's leadership in technology and innovation, we need to take action. It is time to put our money where our innovation is, in small business.

In 1982 when the SBIR program was formed, the U.S. was the undisputed worldwide leader in innovation**.** Then and now America's small businesses are the most innovative sector of the economy and the wellspring of entrepreneurial energy. Yet even though small business employs one third of our scientists and engineers, even though study after study has shown these small businesses produce the most new, good ideas, small businesses are underfunded when compared to Europe and have a very difficult time when enforcing their patents. We are underusing a primary resource for innovating America's future.

The U.S. was once the undisputed leader in developing technology and had clear technology advantage on the battlefield. The U.S. was where innovation happened. Today the rest of the world is catching up and passing us by. Thirty-seven years ago, America dominated venture capital, and we had the best education system, strong patents and private funding for innovation. No other country was even close in these necessary elements. Today, about half the Venture Capital is being invested worldwide, our patent system is severely weakened, we now publish patent applications shortly after they are filed disclosing our technology to the rest of the world, and foreign governments have discovered the benefits of funding innovation

- As a recent Congressional report shows, China is rapidly challenging the U.S. in technology and innovation. Separate from trade practices and taking others' intellectual property, they are putting big money into developing their technology and small businesses.
- The European Union is investing 20% of its R&D in small businesses compared to the US's 5%. [iii] Even France is now putting $13 Billion into "disruptive technologies".[iv]

Patents need to be strengthened. Although it was obvious to SBTC's members that the America Invents Act would be extremely harmful to small business and independent inventors, the full effect of its devastation is now just being felt. The value of patents and patent assets has decreased by over 60% [v] in the first few years after passage of the AIA.

The country has seen similar declines in licensing revenues to inventors.[vi] The America Invents Act (AIA) and the ensued Inter Parties Review (IPR) procedure at Patent Trials and Appeals Board (PTAB) set off the overall declining trend in licensing royalty rate. The average royalty rate has dropped from pre-AIA in 2010 of about 7.1 % to about 4.3 percent in 2017, or about a 40% drop. This particularly adversely affects small business inventors as the lost royalties would traditionally provide the funds to expand a small high-tech business, and the royalty income stream is the only asset from inventions that a bank will use as collateral. Furthermore, in the last eight years, the share of private company licensors has declined substantially. Specifically, small inventing companies and non-practicing entities (NPEs) have to a large extent been shut out of the licensing market and the resulting income, due to large companies' adoption of "efficient infringement" practices.

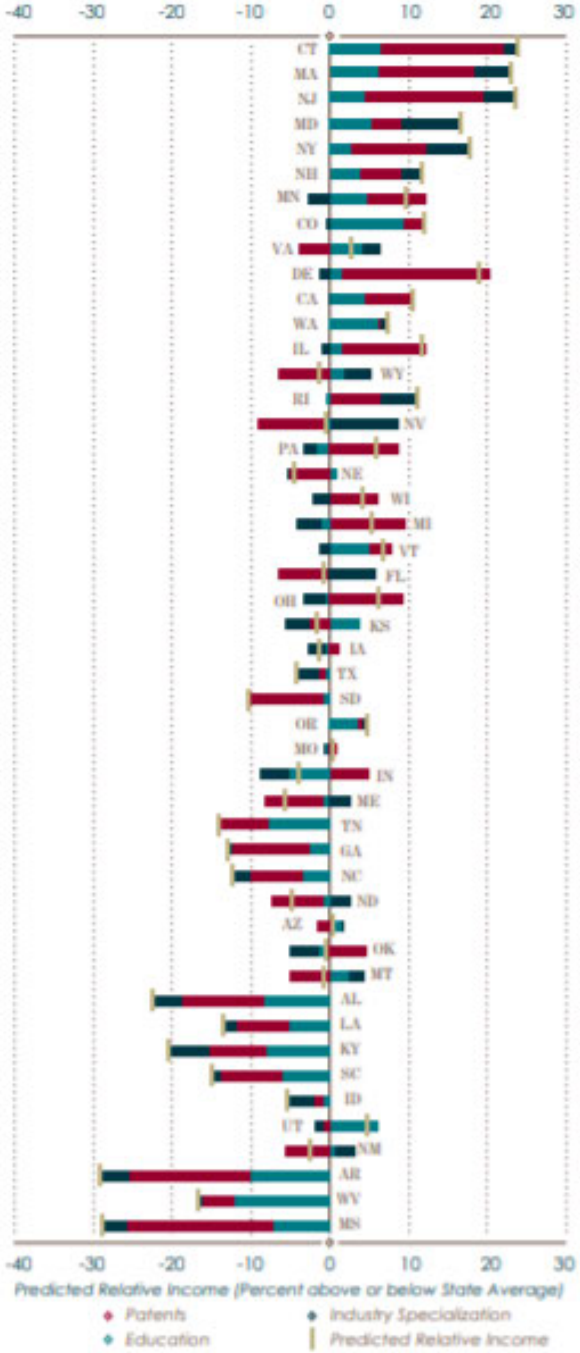
The value of patents in the United States has dropped since the passage of the America Invents Act (AIA) in 2011. This has had a detrimental effect on the American Innovation Ecosystem by reducing the value of the primary asset of new technology-based startups – their patents.
On the issue of patent contributions to the economy data from 1939 to 2012 (73 years) shows how patents used to make a significant contribution to the economy in America.

Page 17 (19/54 of the PDF) of the 2005 Federal Reserve Bank of Cleveland Annual Report 2005 ("Altered States: A Perspective on 75 Years of State Income Growth," Figure 6 (see attachment 1) shows:

> *The authors conclude from figure 6 that the largest factor underlying relative income differences in 2004 is patents, followed by education then industry specialization. This is supported by the predominance of the red bars and their strong positive association with 2004 incomes. Patent data are particularly informative, even though most estimates of profits accruing to firms that hold patents are not particularly high. Bauer, Schweitzer, and Shane interpret the strong patent result shown in figure 6 as income accruing to places that are relatively innovative and produce more patented inventions than other places.*

Figure 6

Predicted Impact of Key Factors on 2004 State Incomes



For more detail, see Paul Bauer, Mark Schweitzer, Scott Shane, *State Growth Empirics: The Long-Term Determinants of State Income Growth*, Working Paper 06-06, Federal Reserve Bank of Cleveland, May 2006, https://www.clevelandfed.org/en/newsroom-and-events/publications/working-papers/working-papers-archives/2006-working-papers/wp-0606-state-growth-empirics-the-long-run-determinants-of-state-income-growth.aspx (see attachment 2). On page 32 (35/55 of the PDF) the authors explain that looking at the period from 1939 to 2004 “high-performing states have large patent stock and educational attainment effects, while for low-performing ones these effects are large and negative.”

The report goes on to explain the math for their conclusion and the reader should view the entire report to best understand all of the nuances of states, industries, and populations. However, their conclusion is the same as that reported in the Federal Reserve Annual Report of 2005.

The third attachment is a Brookings paper entitled "Patenting Prosperity" by Rothwell. The paper provides a later analysis from 1980 to 2012 of metropolitan area invention. They state: *"In recent decades, patenting is associated with higher productivity growth, lower unemployment rates, and the creation of more publicly-traded companies. The effect of patents on growth is roughly equal to that of having a highly educated workforce. A low-patenting metro area could gain $4,300 more per worker over a decade's time, if it became a high-patenting metro area."* Thus, having more enforceable patents means in increase in household wealth of $8,600 in two-worker households.

Other items which SBTC has found:

> *"It is not a coincidence that America has fallen from #1 in Innovation to #11 (according to Bloomberg) since the AIA was passed."*

> *"This drop in patent value has been estimated by some to have cost the American economy 1 to 1.9 trillion dollars."*

For some more SBTC writings, please see www.sbtc.org/patents.

For all of the above reasons, America needs a better method for small businesses to enforce their patents. Eliminating the PTAB would be the best action. However, having a small claims court that would bypass the PTAB would be extremely helpful. A small entity court that enables a small entity to defend its patent rights would provide the due process of an Article III Court and be faster and less expensive.

It is important to remember that entrepreneurs who have a method to monetize their inventions usually go on to start other businesses. Thus, fast resolution of small business patent claims provides growth in new business, and thus a more wealthy America.

Bob Schmidt
Co-Chair, Small Business Technology Council

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[i] Inspiring Tomorrow, U.S. Chamber International IP Index, 7th Edition, February 2019, https://www.theglobalipcenter.com/wp-content/uploads/2019/03/023593_GIPC_IP_Index_2019_Full_04.pdf

[ii]

South Korea Leads World in Innovation as U S. Exits Top Ten https://www.bloomberg.com/news/articles/2021-02-03/south-korea-leads-world-in-innovation-u-s-drops-out-of-top-10#xj4y7vzkg

[iii] Horizon 2020 and the European Innovation Council pilot: a new dynamic for SMEs with breakthrough ideas, https://ec.europa.eu/programmes/horizon2020/en/area/smes

[iv] Jean Baptiste Su, France Creates $13 Billion Disruptive Innovation Fund, Hopes To Become The Next Startup Republic, Jan 17, 2018, 06:19pm https://www.forbes.com/sites/jeanbaptiste/2018/01/17/france-creates-13-billion-disruptive-innovation-fund-hopes-to-become-the-next-startup-republic/#62fcc8e5405e,

[v] An augmented market approach to patent portfolio valuation, Jack Lu, IAM, Sept/OCT 2016, http://www.iam-media.com/Magazine/Issue/79/Features/An-augmented-market-approach-to-patent-portfolio-valuation

[vi] Jack Lu, Licensing Executives Society (LES) 2017 High Tech Deal Term & Royalty Rate Survey, Chapter 5. "Three Surveys, A Decade's Journey: IPR Tax, Alice Shock, and Dynamics of Licensing Markets as Reflected by LES High Tech Royalty Surveys," Available from the Licensing Executives Society, 2019

FEDERAL RESERVE BANK OF CLEVELAND 2005 ANNUAL REPORT

Federal Reserve Bank of Cleveland

2005 Annual Report

www.clevelandfed.org

The Federal Reserve System is responsible for formulating and implementing U.S. monetary policy. It also supervises banks and bank holding companies and provides financial services to depository institutions and the federal government.

The Federal Reserve Bank of Cleveland is one of 12 regional Reserve Banks in the United States that, together with the Board of Governors in Washington, D.C., comprise the Federal Reserve System.

The Federal Reserve Bank of Cleveland, including its branch offices in Cincinnati and Pittsburgh and its check-processing center in Columbus, serves the Fourth Federal Reserve District (Ohio, western Pennsylvania, the northern panhandle of West Virginia, and eastern Kentucky).

Contents

Shrinking the World

Issued in 1876, Alexander Graham Bell's patent for the telephone has been called the most valuable ever issued, revolutionizing the daily lives of ordinary people. In 1935, the first telephone call was made around the world. Although the two men spoke from adjoining rooms in New York, their voices circled the globe.

The Electronic Age

The 1990s to the present are widely considered to be the electronic age: In 1998, Americans averaged 2,300 phone calls a year, and in 2003, computer and Internet capabilities were added to cell phones. One in five people under the age of 30 say the Internet is their main source of information.

President's Foreword

Trade and innovation have profoundly influenced patterns of economic development throughout the ages. The Federal Reserve Bank of Cleveland addressed this topic at some length in our 2003 *Annual Report*. We noted that although trade and technological change invariably favor some industries, skills, and locations more than others, they are ultimately the only sources of rising living standards for all Americans.

During the past several decades, we have witnessed an intense period of globalization and technological change. These forces have affected the United States not only on a national level but on a state level as well. The states, in turn, are focused on how they might influence their *own* economic development paths.

The fact is that per capita income differences among the states have declined significantly over time, primarily because the poorest states have improved their relative positions by so much. Income convergence among the states makes sense: People and businesses are free to locate wherever they wish, and the declining costs of transportation and communication foster mobility. But this convergence is far from complete.

This year's *Annual Report* essay examines factors that might account for differences in the evolution of states' income growth. In seeking to understand why some states appear to be faring much better than others, we conclude that innovation and workforce skills make the difference.

I am proud of the significant strides that our Bank has made in achieving its strategic objectives in 2005: leadership in thought and deed, external focus, and operational excellence. In the Operational Highlights section of this report, we focus on some of these achievements: converting a steadily increasing number of paper checks to Automated Clearinghouse (ACH) debits and Check 21 clearings; becoming one of the nation's largest providers of Treasury services; and leading the effort to consolidate savings bond and TreasuryDirect operations into the Federal Reserve's Pittsburgh and Minneapolis offices.

(l–r): Charles E. Bunch, deputy chairman; R. Chris Moore, first vice president and chief operating officer; Sandra Pianalto, president and chief executive officer; and Robert W. Mahoney, chairman.

The completion of the Bank's Learning Center and Money Museum exemplifies all three of our strategic objectives. The center was designed to educate students and visitors of all ages about what gives money value and how the Federal Reserve supports the integrity of money, banking, and the payments system. I hope that all of our constituents in the Fourth District and beyond will take the opportunity to visit this wonderful new facility located in our Bank's main lobby.

The Bank's success last year was sustained by the guidance and support of our boards of directors in the Cleveland, Cincinnati, and Pittsburgh offices and by the members of our advisory councils.

I am especially grateful for the exemplary service of our outgoing chairman of the board, Robert W. Mahoney (retired chairman and chief executive officer, Diebold, Incorporated). Mr. Mahoney has led our board during the past three years and has served as a director since 2000. His wise counsel and skilled leadership have guided us through many important changes, both internal and external.

Thanks also go to another longtime director, Phillip R. Cox (president and CEO, Cox Financial Corporation). Mr. Cox joined the Cincinnati board in 1994 and served two terms there before joining the Cleveland board in 2000. He has been an energetic contributor, member, and chair of several board committees.

I also offer sincere thanks to V. Daniel Radford (executive secretary–treasurer, Cincinnati AFL–CIO Labor Council) for six years of dedicated service on our Cincinnati board and to Martin G. McGuinn (chairman and CEO, Mellon Financial Corporation), who has served with distinction as our Federal Advisory Council representative for the past three years and as chairman of the council in 2005.

Finally, I offer my profound thanks to the officers and staff of the Federal Reserve Bank of Cleveland. Their contributions in every area of our organization are both inspiring to me personally and essential to our Bank's capacity to change and grow. I know that we will not only meet our future challenges, but that we will achieve new levels of success thanks to our employees' skills, energy, pride, and resourcefulness.

Look to the Federal Reserve Bank of Cleveland for a continued focus on the community, region, and nation. This focus helps us to serve our customers well, to inform economic discourse, and to partner with other organizations that are committed—as we are—to promoting economic prosperity for all of our citizens.

Sandra Pianalto
President and Chief Executive Officer

Farmer with Horse-Drawn Plow, 1930s

Farming was one of the top three occupations in the Fourth District in 1930. The Rural Electrification Act of 1936 brought electric power to many isolated U.S. farms for the first time.

Still a Dominant Force

While both the number of farmers and the percentage of Ohio residents who are farmers have decreased since the mid-twentieth century, average farm size and output have increased.

Altered States: A Perspective on 75 Years of State Income Growth

All of us, it seems, would like to increase our incomes. If elected officials represent our interests, then it follows that these officials would like to help their citizens do just that. Yet boosting collective income levels is a difficult goal to achieve. There are no simple, one-size-fits-all solutions for raising income growth. Still, governments can—and do—try to improve the fortunes of their citizens through initiatives like providing public education systems, recruiting businesses to locate in their region, and assisting in the development and growth of new technologies. In this *Annual Report*, we ask: Why do residents of some states have higher incomes than residents of other states? Why have these income differences persisted for the past 75 years?

To answer these questions, we analyze the patterns of per capita income growth across the 48 contiguous U.S. states from the 1930s to 2004. We find that, over the long run, factors like innovation and a skilled labor force appear to make a big difference in explaining why some states have grown more than others.

Since our research does not examine *specific* policies for state taxation, spending, and regulation, we do not offer advice on any specific policies designed to raise state per capita incomes: Individual policies should be evaluated on cost–benefit criteria. Nevertheless, our findings suggest directions that public policy makers might consider pursuing as they chart their economic development strategies.

This essay begins by providing some facts about state incomes from 1930 to 2004, and we consider these facts in terms of economic growth models. Next, we discuss our own research and how it identifies factors that help to explain the paths of state incomes over this time period. Finally, we address state economic development strategies in light of what we have learned from our research.

THEN AND NOW: The 1930s and the 21st Century

U.S. incomes have risen dramatically over the decades, and how people spend their money has changed as well. Today, the percent of household consumption devoted to transportation expenditures (18 percent) is nearly double that of the 1930s, as lower auto prices, innovations in consumer credit, and rising incomes have made multiple-vehicle ownership widespread. Our food expenditures, on the other hand, have dropped from 34 percent of the U.S. household budget to just 13 percent; low-cost production techniques, refrigeration, and distribution improvements have made this drop possible.

Homeownership rates are also on the rise, increasing from roughly 48 percent in 1930 to 69 percent in 2004. These rising rates were spurred by increasing incomes, the availability of less-expensive suburban land and housing, and financing innovations.

U.S. demographics have changed, too. While the population of the entire United States grew 139 percent from 1930 to 2004, the Fourth Federal Reserve District did not keep pace: West Virginia grew at a meager 5 percent, Pennsylvania at 28 percent, and Kentucky at 58 percent. Ohio's 72 percent growth—the strongest in the District—was still no match for the national average (by comparison, California exploded by 528 percent). In 1930, all four states in the Fourth District were within the top 15 most densely populated states. Although each District state has fallen from its 1930 ranking, Ohio and Pennsylvania still ranked high in the 2004 list.

State Incomes

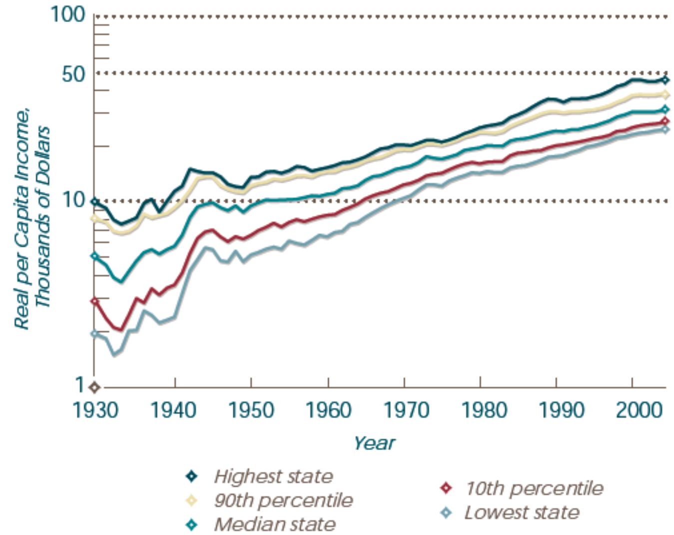
We begin with an analysis of the patterns of per capita income growth across U.S. states. All states have seen their incomes grow in real (inflation-adjusted) terms over the past few generations. Figure 1 shows the income-level growth in all states over the past 75 years: Even accounting for rising prices, the 2004 median of state per capita incomes is more than *six* times higher than it was in 1930.[1] Much of that growth occurred in the expansion that accompanied World War II. The longer-run picture also reveals that the slower growth linked to most recessions is short-lived and that per capita income levels rose faster than inflation in 59 of the past 75 years.

States that had lower incomes in 1930 have tended to grow at a faster pace than those whose incomes were greater at that time. For example, the poorest state—Mississippi—had a per capita income that was roughly one-fifth of the highest-income state at the time, New York. By 2003, the per capita income of the lowest-income state—still Mississippi—was only a little less than *half* of the highest-income state, Connecticut. The progressively smaller gaps among state incomes since the 1930s result in a decline in the standard deviation (a statistic that reveals how tightly state incomes are clustered around the average), as seen in figure 2. This decline is known as convergence—the notion that, over time, the per capita income of states (or countries) will become closer to average.

Within the Fourth Federal Reserve District, the lower-income states of 1930 have also experienced more rapid growth.[2] Kentucky, which had the lowest per capita income of the Fourth District

Figure 1

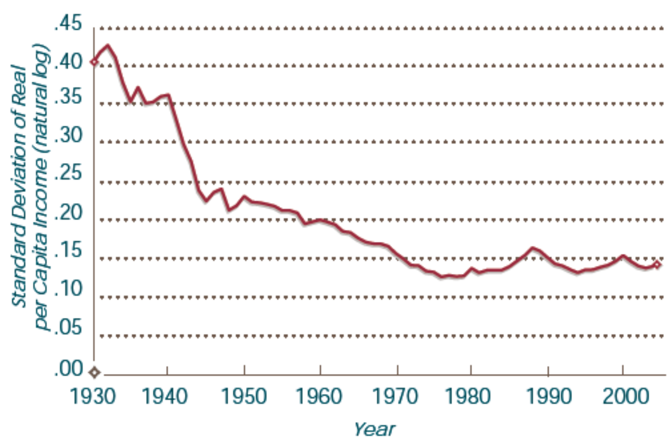
Income Growth



Source: Authors' calculations.

Figure 2

Income Convergence



Source: Authors' calculations.

1 The median is the value below and above which there is an equal number of values or, in this case, where exactly half of the states have higher incomes and half have lower incomes.

2 The Fourth Federal Reserve District includes the entire state of Ohio, western Pennsylvania, eastern Kentucky, and the northern panhandle of West Virginia.

states, experienced the fastest income growth. West Virginia, whose per capita income was low but still well above Kentucky's in 1930, experienced noticeably slower growth than Kentucky. Pennsylvania and Ohio, which had significantly higher incomes than West Virginia and Kentucky, have seen the slowest annual income growth rates in the Fourth District since then.[3]

Does this mean that the economic policies of the lower-income states in the 1930s supported faster income growth than did the policies of the higher-income states? Not necessarily. Economic theory leads us to expect a certain amount of convergence among states.[4] U.S. states share a common set of technologies, and labor and capital are free to locate wherever the return for their services is highest.[5] Over time, the movement of labor and capital should reduce differences in the average amount of capital per worker in a state, a concept known as capital equalization. Applying the basic economic model of total production and growth (see sidebar on Solow and the basics of economic growth), this process should cause incomes to rise in the areas where incomes are lowest.

Evidence shows that capital equalization, which occurs through capital investments in existing plants as well as in the opening and closing of facilities over time, has helped to reduce differences in state income levels. Businesses stand to gain the most when they add capital in places that start with very low relative capital levels (and, therefore, generally lower incomes). Just as the basic economic growth model predicts, the changing location of capital-intensive industries—like

Figure 3

State Manufacturing Employment

Source: Authors' calculations.

manufacturing—in the United States over the past 75 years reveals a clear pattern: States that had lower incomes in 1930 have tended to see, for example, a growing share of total manufacturing employment, while higher-income states have typically seen a declining share (see figure 3). It is exactly this kind of development pattern that should lead to an equalization of capital-per-worker levels within the United States, almost regardless of state policies.

This trend suggests that the reason state incomes have become more equalized is that states' initial levels of capital have become more equalized. In the process, living standards have improved throughout the country. In this simplified version of the growth process, the lower-income states could remain fairly passive and still see their fortunes improve.[6]

3 Kentucky's per capita income growth rate from 1930 to 2004 was 3.0 percent per year. West Virginia's was 2.6, while Pennsylvania and Ohio each had a 2.2 percent annual growth rate.

4 For a basic review of the theory and data, see Gomme and Rupert (2004).

5 The simple version of economic theory neglects states' fixed attributes that might also limit convergence, such as natural resources, access to the ocean, and climate.

6 Realistically, though, states could not sit on their hands. They would still need to build and maintain their public capital stocks just to keep in line with changing national practices.

SOLOW AND THE BASICS OF ECONOMIC GROWTH

Good economic research is built on strong economic models. One of the most durable economic models of the past few decades—the Solow model—shows us what we should expect to see as economies grow.

Fifty years ago, Robert Solow developed what would become a Nobel Prize-winning model of economic growth. Beginning with "A Contribution to the Theory of Economic Growth" in 1956, he crafted a basic model that is still considered a workhorse of macroeconomics today.

The Solow model shows what level of economic growth we can expect using a given amount of capital and labor with a particular level of technology. This is like thinking of the economy as a gradually improving factory that produces one product using both people (labor) and machines (capital).

In this model, per capita income growth comes from a single direction—productivity gains—or, in other words, how our ability to generate per capita income evolves. Productivity gains can be achieved in two ways:

- By increasing the amount of capital for each worker through saving and investment
- Through technical progress or innovation—finding a better way to get things done with what you already have

The Solow model has important implications for how economies grow. It tells us that even if two regions start off with different living standards and different amounts of capital and labor, their amounts of capital per worker will converge. This implies that the regions' per capita income levels will also converge.

Not So Fast

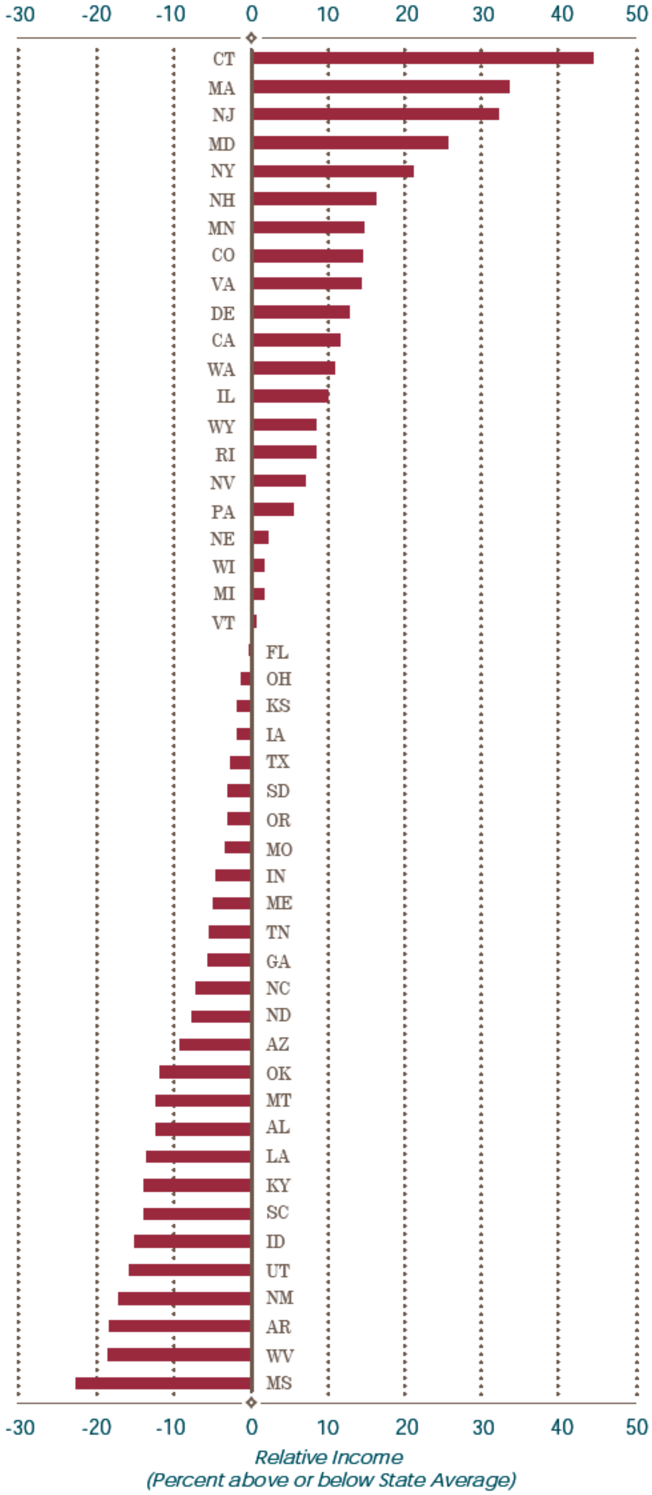
The basic economic model would lead us to expect almost complete convergence by now in state incomes. Has this happened? One way to measure the dispersion of state incomes around the average is with standard deviation; in a country with complete convergence, the standard deviation of state incomes would decline to zero. In fact, the standard deviation of state incomes *has* declined considerably, reaching a minimum in 1976, at roughly 31 percent of the 1930 level. Since then, however, it has risen gradually (see figure 2), with the standard deviation of the 2004 state incomes at roughly 35 percent of the 1930 level. This means that state incomes are now dispersed a bit more widely around the state average than they were in the mid-1970s.[7]

This stalling out of gradual convergence is not evident in all states. Over the past 25 years, lower-income states like Mississippi have actually continued to close in on the median state. But a comparison of state income levels in 2004 (figure 4) shows that substantial income differences remain between low- and high-income states. Why hasn't convergence persisted across the nation? Statistically, the reason is that the income levels reached by our most prosperous states are moving farther away from the median. For example, Connecticut was the highest-income state in both 1976 and 2004: In 1976, it was only 23 percent above the median, whereas it was 47 percent above in 2004.

7 Romer (2000) provides an excellent summary of the basic model and how to calculate the expected rate of convergence.

Figure 4

State Relative Incomes in 2004



Source: Authors' calculations.

The basic economic growth model has no explanation for this divergence of relatively high-income states. Rather, it has a strong prediction that economies sharing technologies should generally tend to converge. In this basic model, states have identical rates of technical progress, and there is no scope for government policies.[8] To help explain the per capita income differences we still observe among states, the basic model must be expanded.

More sophisticated models direct us to recognize that companies and governments might be able to stimulate technical progress through purposeful action. In other words, rather than just relying on labor and capital to move on their own, public officials and private businesses might be able to execute purposeful strategies that expand their abilities to produce goods and services. It is not clear, however, which strategies will best support the evolution of technical progress. We review only the categories that might be particularly relevant within the United States: education levels, taxes and public infrastructure, and patents and technology.[9]

Education Levels. The basic economic growth model does not account for human capital—the accumulated investment in workforce skills. This is important because during the past 75 years, we have seen a tremendous rise in education investment across the country: The share of the U.S. population with college degrees has grown from approximately 4 percent in 1930 to more than 27 percent today.

8 Differing saving rates across states could account for some of this short-run divergence, but if savings move smoothly across state lines, then convergence should be even faster.

9 We did not examine the effects of state programs that offer specific tax breaks or subsidies to businesses in order to attract or retain them. Analysis by the Federal Reserve Bank of Minneapolis (1995) suggests that while such programs benefit the recipients, they do not boost income at the state level.

WHAT CAN EDUCATIONAL ATTAINMENT TELL US?

Just as physical capital is a key determinant of how much an economy can actually produce, human capital is a key determinant of an economy's productive potential. While true human capital can be difficult to quantify, we can use levels of educational attainment as a proxy.

By this measure, U.S. human capital has grown sharply since World War II. For instance, in 1940, less than 25 percent of the U.S. population had completed high school; today, that figure has more than tripled to roughly 85 percent. In the same time span, the percent of college-educated Americans has shot up from less than 5 percent of the U.S. population to more than 25 percent.

Despite this general upward trend, there are still noticeable differences in educational attainment across states, and this has implications for how these economies perform. Among all U.S. states, Massachusetts has the highest proportion of college-educated adults at 36.7 percent and has one of the highest per capita incomes in the United States.

New Hampshire, Minnesota, Georgia, and Alabama have seen some of the largest increases in their share of college-educated citizens in the past 15 years, although Alabama remains one of the states with a relatively low level of bachelor's degree attainment at 22.3 percent. West Virginia—a Fourth District state—has the smallest proportion of college-educated citizens among all states. The other Fourth District states are also below the median, with Kentucky at 21.0 percent, Ohio at 24.6 percent, and Pennsylvania at 25.3 percent. The State-Level Growth Analysis section of the essay addresses the implications of these education patterns for income levels.

More human capital means more productivity, even without incorporating new technology. This may not be the whole story, though. More human capital may also affect which technologies can be adopted. For example, computerization often requires workers to have at least basic programming skills. More human capital may even advance the rate of technological innovation. Empirical studies on international income levels do find a substantial relationship between education levels and income growth, although education differences among countries still fall far short of explaining the remaining income differences.[10] Education differences, large at times, continue to persist and thus may be a factor within the United States as well.

Taxes and Public Infrastructure. What about taxes and public infrastructure? Taxes matter because they lower the amount of money potentially available for private investment, but spending on an improved public infrastructure can also help to boost the economy's productivity. These decisions have potentially offsetting effects on income. In an international study, Kocherlakota and Yi find that U.S. decisions on taxes and public capital have, indeed, been roughly offsetting over a span of many decades.[11] This helps to explain the robust postwar economic growth, despite tax rates that more than doubled during World War II and remained far higher afterward. Public investment also rose dramatically. At the state and local levels, tax and public-spending variations certainly make these factors a plausible source of state differences.

10 Bosworth and Collins (2003) provide recent research accounting for the role of international human-capital differences.
11 Kocherlakota and Yi (1997).

Patents and Technology. Finally, it stands to reason that research and development activity might differ among the states, and this creates a channel through which per capita incomes diverge. Just think about the tremendous effect of electrification—the spread of electricity to nearly universal usage—on twentieth-century society.[12] Advances of this scale cannot help but alter how the economy develops, and they may, at least initially, be unevenly spread through the economy. Smaller increments to our technological base, when cumulated over time, will also improve living standards substantially. Consider the advances of the telephone:

- Early in the twentieth century, operator-assisted rotary phones were still attached to big boxes that housed the ringer.
- The mid-twentieth century saw the telephone become more compact, and modular connections finally allowed phones to be plugged directly into the wall.
- Small, fast, and functional cell phones began replacing many standard phones in the later part of the century and continue to evolve today.

Patents, the most consistent measure of new technical advances, have been employed at each stage of the telephone's progress to protect the many inventors' intellectual property. Patent statistics are typically regarded as an indicator of a broad range of innovative activities rather than as direct producers of income. Past research has connected patent data to more general forms of research and development activities that could vary substantially from state to state.[13]

State-Level Growth Analysis

Even if factors such as human capital, patents, and taxes are likely to have an impact, it remains to be seen just how important these factors are in explaining the differences evident today in state incomes. A recent research project completed at the Federal Reserve Bank of Cleveland by Bauer, Schweitzer, and Shane examines a variety of factors that could influence the evolution of state per capita incomes over time.[14] They use a model grounded in growth theory to consider factors that contributed to per capita income growth in the 48 contiguous U.S. states from 1939 to 2004. This model estimates both the general pattern of convergence among states and the roles of a variety of growth factors like education, patents, taxes, and infrastructure spending.

Part of the model's accuracy stems from including information on the relative income five years earlier, which allows both past investments and past factors outside the model to boost (or lower) state income levels. The model estimates imply that approximately 66 percent of that relative income differential will remain after five years: High-income states will, on average, remain higher-income, and low-income states will remain lower-income.

However, the fact that this estimate is less than 100 percent of the income differential means that the difference between the highest- and lowest-income states should decline each year unless other factors intervene. Without these other factors, income differentials should have shrunk to less than a half of one percent of their starting values over the 65-year period starting in 1939. This pattern is consistent with the income

12 The National Academy of Engineering cites electrification as the most important technical advance of the twentieth century.
13 Griliches (1990) discusses the interpretation of patent statistics as a general economic indicator.
14 Bauer, Schweitzer, and Shane (2006).

INNOVATION IN THE FOURTH DISTRICT

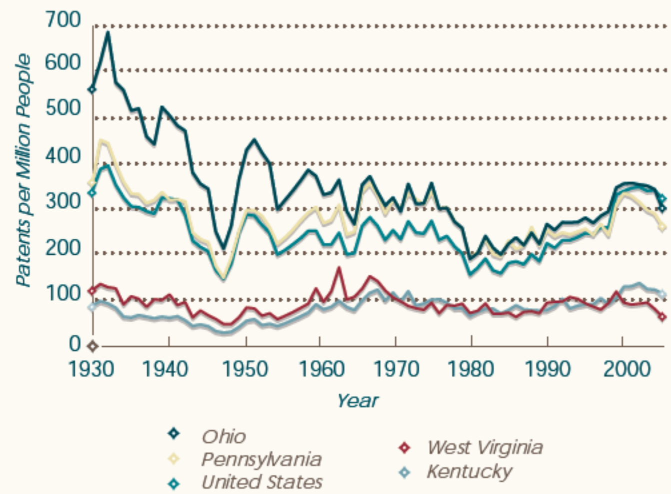
The Fourth District has been the birthplace of many of our nation's inventions: the vacuum cleaner, aluminum, and the Ferris wheel, to name a few. In 1999 alone, our region was granted 4,614 utility patents—that is, "patents for invention." How does our region stack up against the national average, and just who is receiving these Fourth District patents?

In 1930, applicants from Kentucky, Ohio, Pennsylvania, and West Virginia were awarded 7,673 total patents—nearly 20 percent of all patents originating in the United States. After 1930, the number of patents issued to residents of Fourth District states fluctuated greatly, but by 2004, the total granted was 7,216—nearly the same number as was issued 75 years earlier. However, the 2004 total amounted to only 7.7 percent of all patents originating in the United States.

The share of the population involved in research and development activities is better approximated by looking at per capita patents. In 1930, Ohio had significantly more patents per person than the United States as a whole. However, after significantly outpacing the nation for decades, Ohio's per capita patents fell from 566 for every million residents in 1930 to 299 in 2004. Kentucky and West Virginia still have significantly fewer patents per person than the nation, as has been the case since 1917. On a positive note, the number of per capita patents originating in Fourth District states is higher than it was 10 years ago.

Individual companies play a large role in a region's level of patent activity. In just the past five years, more than 35,367 utility patents were awarded to residents of Fourth District states; of these, almost 18 percent were assigned to just 10 companies.

Patents per Capita



Sources: U.S. Department of Commerce, Bureau of the Census; *Annual Report of the Commissioner of Patents* (various years); *www.uspto.gov/index.html;* and authors' calculations.

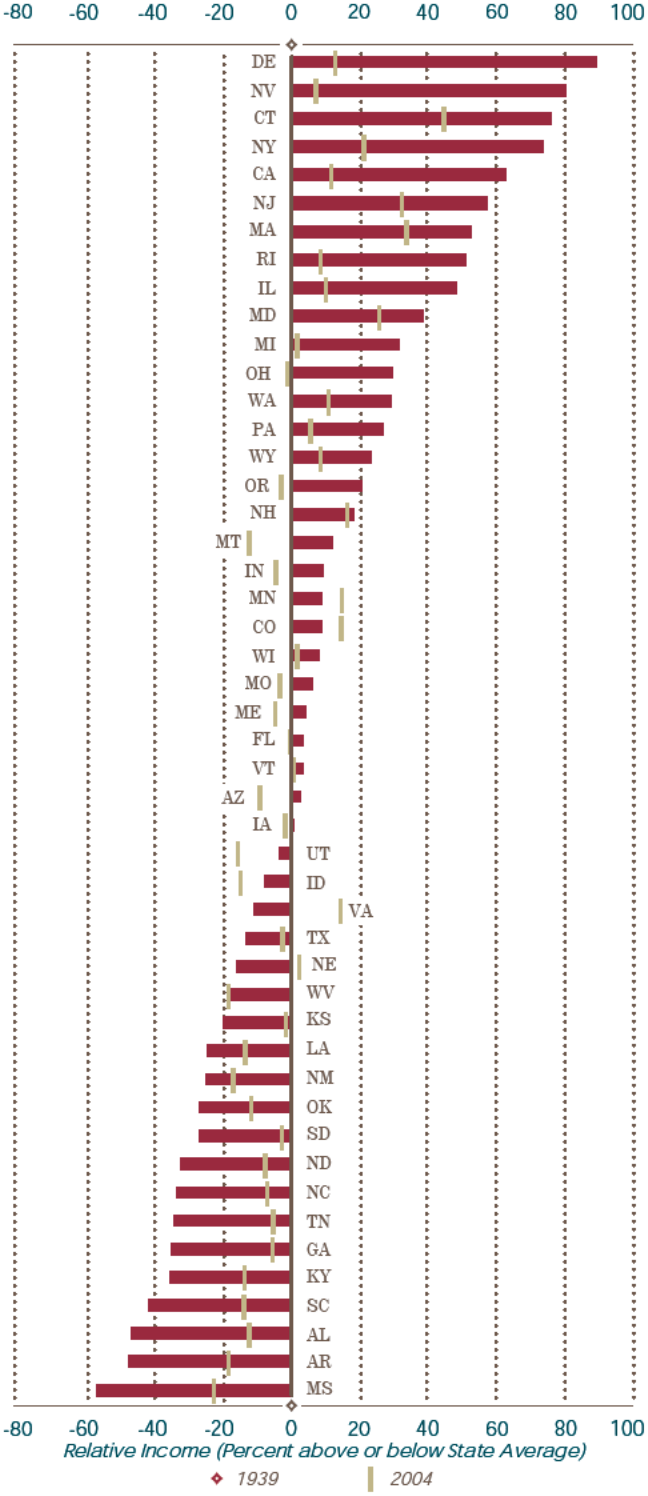
Rank		*Company**	*Industry*	*Fourth District States' Patent Total, 2000–2004*
1	◆	Procter & Gamble	Nondurable Household Products	1,463
2	◆	General Electric Company	Diversified Industrials	1,245
3	◆	SmithKline Beecham Corporation	Pharmaceuticals	604
4	◆	Lexmark International, Inc.	Computer Hardware	558
5	◆	The Goodyear Tire & Rubber Company	Tires	536
6	◆	Lucent Technologies Inc.	Telecommunications Equipment	474
7	◆	Delphi Technologies, Inc.	Automobile Parts	405
8	◆	PPG Industries Ohio, Inc.	Specialty Chemicals	347
9	◆	Air Products and Chemicals, Inc.	Specialty Chemicals	345
10	◆	Rohm and Haas Company	Specialty Chemicals	324

Sources: *www.uspto.gov/web/offices/ac/ido/oeip/taf/asgstc/oh_stc.htm; www.money.cnn.com;* and authors' calculations.

* Patent origin is determined by the residence of the first-named inventor listed on the patent grant.

Figure 5

State Relative Incomes in 1939



Source: Authors' calculations.

convergence predicted by the basic growth model with factor mobility and is also consistent with past studies.[15]

This estimated rate of convergence implies that essentially no part of the 1939 state-income distribution remains today. Yet considering the 1939 state relative incomes, shown in figure 5, it is evident that some states have retained their relative status while others have moved substantially. Connecticut, New Jersey, and Massachusetts were all relatively high-income states, and they ended 2004 as the three highest-income states. Mississippi and Arkansas, the lowest-income states in 1939, are still among the lowest-income states today. On the other hand, Nevada's relative income has fallen, while Tennessee's and Alabama's incomes have moved up considerably in the distribution.

Bauer, Schweitzer, and Shane identify several factors as statistically reliable indicators for growth: education levels, patents, and industry specializations.[16] Figure 6 shows the model's predicted 65-year impact of these factors on state incomes in 2004 (see figure 4 to compare these predicted incomes to the actual 2004 incomes). Each factor is represented by a colored bar specifying how much that factor boosted or reduced the income prediction of each state. Take Ohio as an example: Ohio's history of above-average patent levels boosts its income prediction by almost 10 percent, while its slightly below-average levels of education and industry specialization have small negative effects on Ohio's predicted income in 2004. In cases where one of the factors offsets the others (states with both positive and negative bars), the

15 See Barro and Sala-i-Martin (1995) for examples and for citations to earlier work on the topic.

16 They also identify a statistically significant role for climate variables, although the effect of climate on income is not nearly as large a factor as the others.

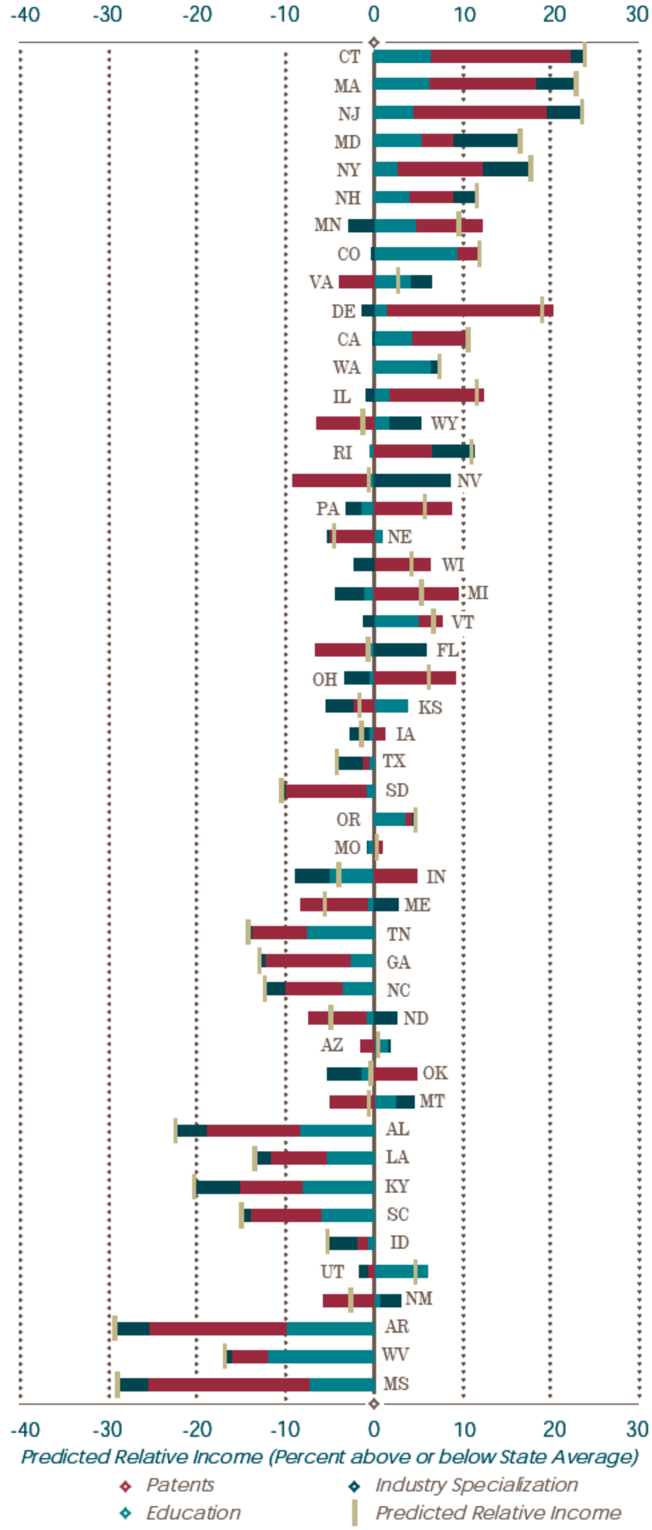
predicted relative income is the sum of the positive and negative effects, marked by the gold lines. This means that although it looks like Ohio's predicted 2004 income is almost 10 percent above average, it is really only approximately 6 percent above.

Long-run variations in state education levels, patents, and industry specializations explain much of the 2004 income differences. If the predicted rankings from the authors' model were perfect, the bars in figure 6 would *steadily* shift from the bottom-left to the top-right. This is not the case, but, in line with the model's prediction, negative bars are typically seen toward the bottom (lower-income states), while positive bars are almost exclusively seen toward the top. Also note that the scale of the predicted effects is generally smaller than the actual 2004 values (shown in figure 4) but not by a large amount. Collectively, this visual evidence shows that the model does account for much of the current differences in state income levels.

The authors conclude from figure 6 that the largest factor underlying relative income differences in 2004 is patents, followed by education then industry specialization. This is supported by the predominance of the red bars and their strong positive association with 2004 incomes. Patent data are particularly informative, even though most estimates of profits accruing to firms that hold patents are not particularly high. Bauer, Schweitzer, and Shane interpret the strong patent result shown in figure 6 as income accruing to places that are relatively innovative and produce more patented inventions than other places.

Figure 6

Predicted Impact of Key Factors on 2004 State Incomes



Source: Authors' calculations.

Listing the states with the highest levels of patents per capita at the end of the sample reveals why this variable works so well: Delaware ranks first, New Jersey second, and Connecticut third. In terms of income, Connecticut is first and New Jersey is third; both have shown surprising income growth. Most lower-income states have very low levels of patenting per capita. Delaware deviates from the pattern noticeably in that its income level is not among the top states, but the overall correlation is clear in the data.

Bauer, Schweitzer, and Shane suggest that these differences likely reflect higher (or lower) levels of knowledge-building activities (which are correlated with patents) within these states. In their interpretation, something about Connecticut and New Jersey makes them more active in generating innovation, although the specific sources of these advantages are not identified. For example, patents might be a proxy for success in commercialization of technology.

The education factor in figure 6 comes from combining high school and college completion statistics. Colorado, Connecticut, and Massachusetts are the current education leaders; again, their income levels stand out. Education is also a fairly reliable indicator of lower income levels and weak convergence, with West Virginia and Arkansas having the lowest education scores. It is important to see that while patents and education levels are correlated, the statistical procedure used by the authors indicates that these factors are distinct from one another.

Industry specialization is yet another reliable indicator of state growth differences. For instance, states with larger-than-usual mining incomes tend to grow more slowly than states with other specialties. States with higher levels of manufacturing also tend to grow more slowly, even though these states initially had higher incomes. Indeed, both the familiar manufacturing centers, like Ohio and Indiana, and the new manufacturing centers of the South, like Mississippi and Kentucky, are estimated to have lower income levels due to their industry specializations. Today, the states with larger-than-average service sectors are the ones estimated to have experienced more income growth (see the dark-blue bars in figure 6).

State tax differences and investments in infrastructure (in the form of roads) play smaller roles in interstate income differences and typically are statistically insignificant, as are banking deposits. Climate differences are statistically valid for predicting income growth, with warmer and drier states showing more income growth, yet the effects of the climate variables are substantially smaller and more-erratic predictors of 2004 income levels.

Overall, Bauer, Schweitzer, and Shane's study emphasizes the role of knowledge building—through research and education—in aiding income growth. A separate study (see sidebar on dashboard indicators) analyzing the growth patterns of U.S. metropolitan areas during the past 10 years corroborates this role: Although this study differs considerably in its methodology, it agrees that patents and education are associated with higher incomes in metropolitan areas.[17]

17 Eberts, Erickcek, and Kleinhenz (2006).

DASHBOARD INDICATORS

Not surprisingly, experts in many metropolitan areas have sharpened their focus on increasing regional growth prospects. A good example is "Dashboard Indicators for the Northeast Ohio Economy," a paper by Randall Eberts, George Erickcek, and Jack Kleinhenz. This study analyzes which local economic indicators have contributed to growth in terms of output, employment, per capita income, and productivity in more than 100 metro areas.

The authors' research was supported by The Fund for Our Economic Future, which seeks to advance a regional economic development agenda that can lead to long-term economic transformation.[1]

The "Dashboard" study considers a broad set of state-income-growth variables. Forty economic indicators were combined into eight summary measures of related variables: skilled workforce, assimilation center (a set of variables focused on recent immigrants), racial inclusion, legacy of place, income equality, locational amenities, business dynamics, and urban/metro structure.[2] The statistically derived factors combine the effects of underlying variables that are highly correlated among the metro areas.

The authors then analyze these factors for their effect on economic growth measures, including per capita income. The four factors that contribute to higher income growth are—in order of importance—skilled workforce (which includes patents), urbanization/metro governance (which focuses on the governmental structure), income equality, and locational amenities (as evaluated in *Places Rated Almanac*).[3] They also find that the legacy-costs factor (which includes their measures for industry specialization) is significantly associated with lower income growth.

The skilled-workforce factor is consistent with both general education results and growth in the technology base in the Bauer–Schweitzer–Shane project (see the State-Level Growth Analysis section); these two distinct measures are highly correlated in recent metropolitan-level data and thus are combined into one measure. The "Dashboard" study estimates that the skilled-workforce factor is at least twice as important as the other explanations of income differences.

The authors' legacy-cost variable largely reflects the share of the workforce in manufacturing, which the Bauer–Schweitzer–Shane study also noted as a factor that held back income growth. The additional factors that the authors identify as statistically significant point to issues that local economic development economists have observed as appearing to be new, potential growth sources.

These two studies bring new empirical findings to the question of how communities can boost their income levels. As is true with most growth models in the national and international arenas, education levels stand out as important factors, but both of these studies also help to direct attention to other factors that matter. As such, they help to push the focus of economic development beyond just the recruitment and retention of capital investments.

1 The Fund for Our Economic Future (2006).

2 For example, "legacy of place" combines the number of government units in the metropolitan area, a crime index, a climate index, the percent of houses built before 1940, and the total number of layoffs and hires within the economy (a measure of how dynamically an economy is adapting to either positive or negative shocks). For descriptions of the other factors, please refer to Eberts, Erickcek, and Kleinhenz's report, which can be found at *www.clevelandfed.org/Research/Workpaper/2006/index.cfm.*

3 Savageau (1999).

Lessons for the States

Does the rising importance of knowledge in the economy necessarily mean that industries like manufacturing—a prominent one in the Fourth District—no longer have a place? After all, the results show that a manufacturing concentration negatively affects a state's income, at least when the model holds the state's other characteristics—most importantly its income history—constant. As it turns out, in the 1930s, manufacturing and high state income levels tended to go together.[18] But in the model estimates, the negative effect of manufacturing and the general pattern of income convergence have largely eliminated the income advantage that manufacturing once had. The negative estimates for the industry-specialization factor likely reflect the importance of circumstances that have particularly affected manufacturers over this 75-year period.[19]

Statistically speaking, little correlation remains today between a state's manufacturing share and its income level. This leaves us close to the premise that manufacturing's expected return to investment should be equalized across the economy. In this case, there is no reason for states to avoid manufacturing, but there is also no reason to favor it over other economic activities.

A SHIFT IN FOURTH DISTRICT OCCUPATIONS

Goods-producing industries such as steel and farming have historically been the lifeblood of the Fourth District economy. But since the 1930s, shifts in the labor force have caused this region to reevaluate its place in the national economy.

In 1930, the Fourth District's three largest occupations—laborer, operative worker, and farmer—accounted for nearly 30 percent of its labor force. While these occupations remain significant to the Fourth District's vitality, they accounted for just over 10 percent of its labor force in 2004, and farmer dropped from the third-most-common job to the forty-ninth.

At the same time, health-care occupations have seen a significant increase, with nurses, hospital attendants, and medical technicians accounting for nearly 5 percent of employment today, versus only about $^1/_2$ percent in 1930. This trend in occupational employment shows a movement in Fourth District states toward a more service-based economy, similar to the trend in the rest of the country.

18 The correlation in 1930 was 0.57.

19 International trade may have played an increasingly important role in manufacturing activity's value to a state's income during our sample period, but we did not examine this proposition directly.

The results suggest a possible exception for at least some manufacturing companies: the exceptional innovators. Many states with high levels of patents over the past 10 years generate a large fraction of their patents in companies with a manufacturing link to the state, even if their manufacturing facilities are now often located elsewhere. Several of the companies listed as top producers of patents in Fourth District states between 2000 and 2004 are global companies with relatively few local manufacturing sites. Innovative companies like this appear to offer benefits to their states potentially beyond the direct value of their activities, even though these benefits are often thought of as supplemental.

Innovation and education certainly stand out in the Bauer–Schweitzer–Shane study; and past research has also pointed in this direction, although the scale of the factors was less certain.[20] However, it is one thing to establish that being a center of innovation or having a large number of highly educated residents—or both—promotes faster income growth. It's another to determine which state and local policies can be most effective.

Policy initiatives should be evaluated on cost–benefit criteria, and states can differ in their abilities to get the most out of any policy initiative. For these reasons, growth-promoting strategies should not be blindly pursued. For example, subsidizing companies that register their patents in particular states or localities would probably not promote much growth, unless the companies also relocated their research activities. Furthermore, any realistic plan should take into account the activities of other areas: Not every region can be the preeminent center of the latest hot technology.

To be effective, all policies require careful thought and planning. Research evaluating specific policy options will necessarily be more focused on the details that make policies successful. We intend to follow up this work with additional research on how the identified factors can be boosted in a state or region. Indeed, conferences hosted by the Federal Reserve Bank of Cleveland on the economics of education policy over the past two years have been focused on reaching a better understanding of the economic policy issues of education reform.

Caveats aside, the evidence provided by the growing study of expanded growth models suggests pursuing policies that increase the knowledge base of the region. This may sound like the mantra of the Internet age, but the results presented here show that innovation has been pivotal to income growth at the state level since the 1930s.

20 For example, see Glaeser and Saiz (2004).

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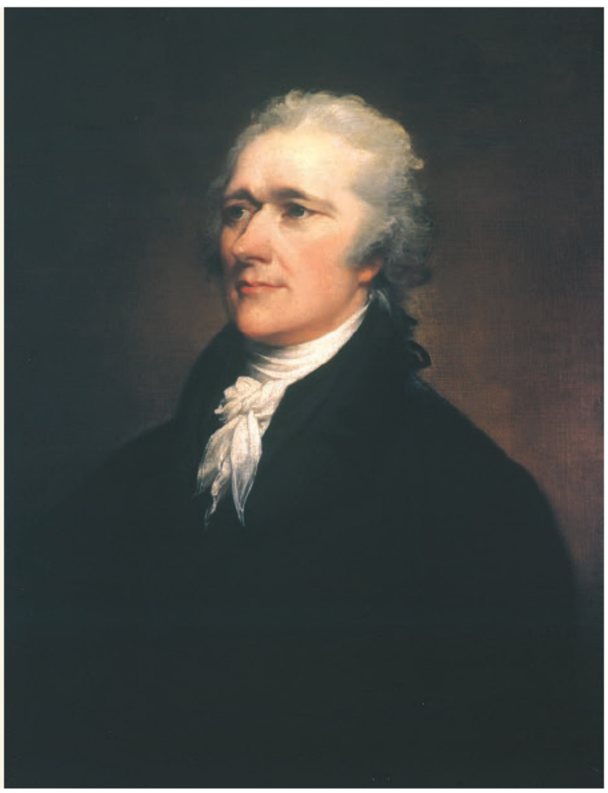
A Depressing Reality

Before the Great Depression, education was one of the top priorities in America. But by 1933, two hundred thousand teachers were unemployed, 2.2 million children were out of school, and two thousand rural schools had failed to open. Even if children were fortunate enough to go to school, class and racial barriers prevented many of them from going to college.

The Rise of Universal Education

Enrollment in prekindergarten through eighth grade at private and public schools rose to 40.0 million children in 2004. Private- and public-college enrollment of undergraduates and grad students hit a record level in 2004 at 17.4 million, and the share of bachelor's degrees obtained by African Americans, Caucasians, and Hispanics have all increased over the years.

Operational Highlights: Even the Treasury Needs a Bank



Alexander Hamilton,
first Secretary of the U.S. Treasury

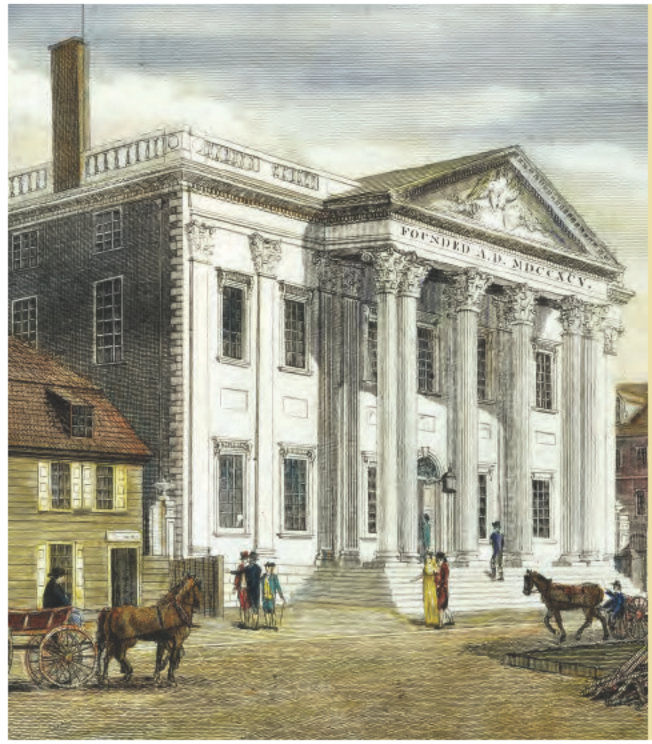
Hamilton's Treasury

When Alexander Hamilton reported to work as the first Secretary of the U.S. Treasury on September 14, 1789, he faced daunting fiscal challenges: The new nation's public credit was in shambles, with the outstanding public debt trading at significant discounts; soldiers in the federal army—in fact, all federal employees—needed their paychecks; and the federal government had no liquid bank balances, relying instead on loans from the Bank of New York and the Bank of North America to begin operations.

Much of Hamilton's attention in that first year was, naturally, focused on policy matters, such as whether the federal government should assume the Revolutionary War debts of the states and whether the nation needed a national bank.

But Hamilton also devoted considerable attention to the day-to-day financial business of the government. In that first year, the federal government's revenues consisted almost entirely of the $4.4 million earned in customs receipts, of which 55 percent was spent on debt service and another 15 percent on the military. But how could the federal government reliably and efficiently collect revenues from all customs and land sales across a land mass of 900,000 square miles, an area larger than any European state of the period save the Russian Empire? How could the Treasury combine funds from borrowings, note issues, and taxes to meet its daily obligations? And how could the Treasury assure the many creditors of the new nation, foreign and domestic, that the obligations owed them would be paid in full and on time?

Hamilton addressed those challenges by running the Treasury the way he knew how—like a business enterprise. Hamilton was among the few founding fathers with substantial commercial business experience, having worked for several years in a thriving St. Croix trading enterprise before coming to the American colonies in 1772. In his state papers, Hamilton emphasized the importance of paying the government's bills on time, collecting revenues in an efficient manner, and maintaining cordial relationships with creditors and other stakeholders.[1]



First Bank of the United States, Philadelphia, 1799

With 27 employees, the Treasury was the largest department in the new government, but it did not have sufficient national reach or commercial expertise to efficiently execute its day-to-day operations. The Treasury needed a *fiscal agent* with a national presence to make payments, collect funds owed to the government, and manage relationships with the government's creditors. The Bank of the United States—our nation's first central bank—began serving in 1791 as the Treasury's first fiscal agent, a role that the Federal Reserve System continues to play today.

1 Hamilton's state papers, *Report on Public Credit* (January 9, 1790) and *Report on a National Bank* (December 13, 1790), are particularly instructive in this area.

Savings bonds

Liberty Loan bonds

The Federal Reserve as Fiscal Agent

The Federal Reserve Act was signed into law in December 1913. Toward the end of 1914, the 12 Federal Reserve Banks opened for business, but they only gradually took on the fiscal agency role. In 1915 and 1916, the Reserve Banks were designated as depositories to maintain the Treasury's bank account, facilitating nationwide collection and disbursement of funds for the federal government. In 1917, Reserve Banks began handling an unprecedented volume of securities processing associated with the Liberty Loan bonds and Victory Notes issued to finance U.S. involvement in World War I. In 1921, the Treasury closed its network of regional offices, which dated to the mid-1840s. The duties of those offices to hold collateral for government funds held on deposit at commercial banks and to distribute the nation's currency and coin were transferred to the Federal Reserve.

The partnership between the Treasury and the Federal Reserve continued to grow in succeeding decades, with the Reserve Banks assuming an increasing share of the back-office duties involved in day-to-day Treasury operations. Among the Federal Reserve's fiscal agency activities today are collecting and holding balances due the Treasury; making and receiving payments for the federal government using checks, Automated Clearinghouse (ACH), and wire transfers; printing, issuing, and retiring U.S. savings bonds; managing the relationship between the Treasury and its creditors, i.e., purchasers of government securities; and processing U.S. postal money orders. In 2005, the Federal Reserve spent $376 billion, or nearly 15 percent of its total spending, on Treasury support.

Using the Federal Reserve as its fiscal agent has provided the Treasury with an alternative to operating a national financial institution of its own. Like Alexander Hamilton, who moved most of the Treasury's payment processing to the Bank of the United States, today's Treasury has outsourced much of its daily payment and debt-processing activities to the Federal Reserve.

Technology and Consolidation

The Treasury's relationship with the Federal Reserve Banks is a "dynamic partnership based on common goals of delivery of high quality service and efficiency of operations."[2] The Treasury and the Reserve Banks have used technology and consolidation to cut costs and improve the delivery of services to millions of U.S. citizens.

Services such as Treasury securities and savings bond processing, which, as recently as 1990, were provided by all 35 main offices and branches in the Federal Reserve System, have now been consolidated into just two locations. Treasury check services, which were handled in 45 Federal Reserve check-processing locations until 1990, have also been consolidated into two offices.

The Treasury and the Federal Reserve have migrated to straight-through processing of some activities, using the Internet, telecommunications, and data processing technology as more efficient and cost-effective substitutes for manual processing. By using ACH to convert checks to electronic payments, certain types of check clearing that used to take two or three weeks can now be done overnight, lowering the cost of clearing and of after-the-fact exceptions processing. By using the Internet, consumers can conduct business with the Treasury and federal agencies 24/7.

Straight-through processing illustrates one of the most remarkable accomplishments of the Treasury/Federal Reserve collaboration: the transition from a system dominated by paper processing to one with a large electronic component. The Federal Reserve Bank of Cleveland has played an important role in that evolution.

Transactions Converted from Paper to Electronics

Category	1970	2005
Federal payments made electronically	0%	79%
Savings bond applications received electronically	0%	65%

The Cleveland Bank's Role in Supporting the U.S. Treasury

In the 1980s, the Federal Reserve Bank of Cleveland's role in providing fiscal agency services to the Treasury was much like those of the other 11 Reserve Banks. However, by 2005, the Cleveland Reserve Bank had become one of the largest providers of Treasury services in terms of staff levels, comprising 27 percent of the System's total.

2 Bureau of the Public Debt. 2003. *Public Debt Strategic Plan 2003–2008. www.publicdebt.treas.gov/oa/oastrategicplan.pdf*, accessed April 3, 2006.

A number of factors contributed to the Cleveland Bank's role in providing Treasury services:

- Transfer of activities from the Treasury to the Federal Reserve, such as the processing of redeemed bonds, which was moved from the Treasury's office in Parkersburg, West Virginia, to the Federal Reserve Bank of Cleveland's Pittsburgh Branch in 1999
- Consolidation of Treasury services once performed in all Federal Reserve Districts into progressively fewer offices, such as the consolidation of Treasury securities and savings bond servicing into the Pittsburgh and Minneapolis Federal Reserve offices in 2005
- Treasury efforts to move services from commercial banks and other private-sector providers into the Federal Reserve, such as the *Over-the-Counter Paper Check Conversion to ACH* program that is now centralized in the Cleveland office
- Initiatives chosen by the U.S. Treasury to be sourced from the Federal Reserve, especially those that were placed in the Fourth District for production and day-to-day management, such as the *Pay.gov* program, which Web-enables and makes electronic many Treasury and other federal collection transactions that were once done with paper

CASH AND CHECK OPERATIONS

Fiscal agency functions were not the only Federal Reserve operations to be affected by consolidations in recent years. In 2004, the Federal Reserve Bank of Cleveland's Cincinnati office began processing cash for financial institutions in the Federal Reserve's Louisville territory. In 2006, the Bank's Cleveland office is scheduled to absorb the cash activities of the Federal Reserve office in Buffalo, New York.

Check-processing volume in the Fourth District has grown from an average of 6.3 million checks per day in 2002—before consolidation began—to 7.6 million in 2005, despite a 38 percent decline in overall check volume in the Federal Reserve System. The Cleveland Bank's Cincinnati office, in addition to serving its own territory, now clears checks for territories once served by the Charleston, Indianapolis, and Louisville Federal Reserve offices. In mid-2005, the Cleveland office absorbed the check-processing operation of the Federal Reserve's Detroit office, and in early 2006, Cleveland and Cincinnati will absorb all check processing from the Cleveland Bank's Columbus office.

Federal Reserve check-processing operations are also being impacted by Check 21, which became effective in October 2004. The volume of checks being converted to images or to substitute checks rose rapidly throughout 2005. By year's end, such checks represented approximately 5 percent of the number, and roughly 20 percent of the dollar value, of checks processed by the Federal Reserve.

Treasury Retail Securities

The Treasury Retail Securities Department, housed in Cleveland's Pittsburgh Branch, led the System's effort to consolidate savings bond and Treasury-Direct operations into the Federal Reserve's Pittsburgh and Minneapolis offices. The Treasury expects the consolidation to result in $30 million in annual savings for U.S. taxpayers.

In 2005, the Pittsburgh office processed 5.7 million savings bond applications, printed and mailed 32 million bonds, and redeemed 48 million bonds. Also, as part of its fiscal agency activities, Pittsburgh managed the Treasury's book-entry and payroll savings bond programs and its TreasuryDirect bond and note-purchasing program.

eGovernment

The eGovernment function, housed in Cleveland, is responsible for the conversion of paper checks—received over the counter and at government-contracted lockbox operations—to ACH debits and Check 21 clearings. These paper-check-conversion programs reduce the Treasury's clearing costs and its exposure to risk from bounced checks.

The programs have grown significantly in the past year: The Cleveland office currently receives over-the-counter check images from a total of 463 government sites on six continents and U.S. Navy ships at sea. In 2005, the Cleveland office handled 1.9 million over-the-counter payments worth $1.75 billion. Lockbox paper-check conversion, launched in 2005, involved 415,000 transactions worth $456 million.

The eGovernment function also administers the Pay.gov program, which involves collections management for 87 federal agencies, which themselves manage 208 separate federal programs. Pay.gov handles payments received over the Web; the hosting of electronic versions of paper forms, which can be completed on the Web; and the electronic presentment of bills for federal services, which can be executed there. Pay.gov offers consumers and businesses electronic access to information and transaction processing, while reducing the Treasury's operating costs.

The U.S. Treasury anticipates that $30 billion in transactions will move across Pay.gov in 2006, including $24 billion associated with the Customs and Border Protection Service.

Principles That Stand the Test of Time

Alexander Hamilton could not possibly have fore-seen the way technology would transform Treasury operations or the role that the Federal Reserve System would play in that transformation. But Hamilton would no doubt recognize the business principles that guided the process: timeliness, efficiency, and customer service.

Financial Statements

The firm engaged by the Board of Governors for the audits of the individual and combined financial statements of the Reserve Banks for 2005 was PricewaterhouseCoopers LLP (PwC). Fees for these services totaled $4.6 million. To ensure auditor independence, the Board of Governors requires that PwC be independent in all matters relating to the audit. Specifically, PwC may not perform services for the Reserve Banks or others that would place it in a position of auditing its own work, making management decisions on behalf of the Reserve Banks, or in any other way impairing its audit independence. In 2005, the Bank did not engage PwC for any material advisory services.

Management's Report on Responsibility for Financial Reporting

March 2, 2006

To the Board of Directors of the Federal Reserve Bank of Cleveland:

The management of the Federal Reserve Bank of Cleveland ("FRBC") is responsible for the preparation and fair presentation of the Statement of Financial Condition, Statement of Income, and Statement of Changes in Capital as of December 31, 2005 (the "Financial Statements"). The Financial Statements have been prepared in conformity with the accounting principles, policies, and practices established by the Board of Governors of the Federal Reserve System and as set forth in the *Financial Accounting Manual for the Federal Reserve Banks* ("Manual"), and as such, include amounts, some of which are based on judgments and estimates of management. To our knowledge, the Financial Statements are, in all material respects, fairly presented in conformity with the accounting principles, policies and practices documented in the Manual and include all disclosures necessary for such fair presentation.

The management of the FRBC is responsible for maintaining an effective process of internal controls over financial reporting including the safeguarding of assets as they relate to the Financial Statements. Such internal controls are designed to provide reasonable assurance to management and to the Board of Directors regarding the preparation of reliable Financial Statements. This process of internal controls contains self-monitoring mechanisms, including, but not limited to, divisions of responsibility and a code of conduct. Once identified, any material deficiencies in the process of internal controls are reported to management, and appropriate corrective measures are implemented.

Even an effective process of internal controls, no matter how well designed, has inherent limitations, including the possibility of human error, and therefore can provide only reasonable assurance with respect to the preparation of reliable financial statements.

The management of the FRBC assessed its process of internal controls over financial reporting including the safeguarding of assets reflected in the Financial Statements, based upon the criteria established in the "Internal Control—Integrated Framework" issued by the Committee of Sponsoring Organizations of the Treadway Commission (COSO). Based on this assessment, we believe that the FRBC maintained an effective process of internal controls over financial reporting including the safeguarding of assets as they relate to the Financial Statements.

Sandra Pianalto

President
and Chief Executive Officer
Federal Reserve Bank of Cleveland

R. Chris Moore

First Vice President
and Chief Operating Officer
Federal Reserve Bank of Cleveland

Laurence Cuy

Senior Vice President
and Chief Financial Officer
Federal Reserve Bank of Cleveland

PRICEWATERHOUSECOOPERS

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Report of Independent Accountants

To the Board of Directors of the Federal Reserve Bank of Cleveland:

We have examined management's assertion, included in the accompanying Management Assertion, that the Federal Reserve Bank of Cleveland ("FRB Cleveland") maintained effective internal control over financial reporting and the safeguarding of assets as of December 31, 2005, based on criteria established in *Internal Control—Integrated Framework* issued by the Committee of Sponsoring Organizations of the Treadway Commission. FRB Cleveland's management is responsible for maintaining effective internal control over financial reporting and safeguarding of assets. Our responsibility is to express an opinion on management's assertion based on our examination.

Our examination was conducted in accordance with attestation standards established by the American Institute of Certified Public Accountants and, accordingly, included obtaining an understanding of internal control over financial reporting, testing and evaluating the design and operating effectiveness of internal control, and performing such other procedures as we considered necessary in the circumstances. We believe that our examination provides a reasonable basis for our opinion.

Because of inherent limitations in any internal control, misstatements due to error or fraud may occur and not be detected. Also, projections of any evaluation of internal control over financial reporting to future periods are subject to the risk that the internal control may become inadequate because of changes in conditions, or that the degree of compliance with the policies or procedures may deteriorate.

In our opinion, management's assertion that FRB Cleveland maintained effective internal control over financial reporting and over the safeguarding of assets as of December 31, 2005 is fairly stated, in all material respects, based on criteria established in *Internal Control—Integrated Framework* issued by the Committee of Sponsoring Organizations of the Treadway Commission.

This report is intended solely for the information and use of management and the Board of Directors and Audit Committee of FRB Cleveland, and any organization with legally defined oversight responsibilities and is not intended to be and should not be used by anyone other than these specified parties.

PricewaterhouseCoopers LLP

March 8, 2006
Cleveland, Ohio

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Report of Independent Auditors

To the Board of Governors of the Federal Reserve System and
the Board of Directors of the Federal Reserve Bank of Cleveland:

We have audited the accompanying statements of condition of the Federal Reserve Bank of Cleveland (the "Bank") as of December 31, 2005 and 2004, and the related statements of income and changes in capital for the years then ended, which have been prepared in conformity with the accounting principles, policies, and practices established by the Board of Governors of the Federal Reserve System. These financial statements are the responsibility of the Bank's management. Our responsibility is to express an opinion on these financial statements based on our audits.

We conducted our audits in accordance with auditing standards generally accepted in the United States of America. Those standards require that we plan and perform the audit to obtain reasonable assurance about whether the financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation. We believe that our audits provide a reasonable basis for our opinion.

As described in Note 3, these financial statements were prepared in conformity with the accounting principles, policies, and practices established by the Board of Governors of the Federal Reserve System. These principles, policies, and practices, which were designed to meet the specialized accounting and reporting needs of the Federal Reserve System, are set forth in the *Financial Accounting Manual for Federal Reserve Banks* and constitute a comprehensive basis of accounting other than accounting principles generally accepted in the United States of America.

In our opinion, the financial statements referred to above present fairly, in all material respects, the financial position of the Bank as of December 31, 2005 and 2004, and results of its operations for the years then ended, on the basis of accounting described in Note 3.

PricewaterhouseCoopers LLP

March 8, 2006
Cleveland, Ohio

Comparative Financial Statements

Statements of Condition *(in millions)*

	December 31, 2005	December 31, 2004
Assets		
Gold certificates	$ 453	$ 452
Special drawing rights certificates	104	104
Coin	55	52
Items in process of collection	820	814
U.S. government securities, net	31,692	31,004
Investments denominated in foreign currencies	1,712	1,757
Accrued interest receivable	247	217
Interdistrict settlement account	833	—
Bank premises and equipment, net	185	183
Interest on Federal Reserve notes due from U.S. Treasury	—	234
Other assets	73	85
Total assets	**$ 36,174**	**$ 34,902**
Liabilities and Capital		
Liabilities:		
Federal Reserve notes outstanding, net	$ 31,457	$ 29,103
Securities sold under agreements to repurchase	1,289	1,315
Deposits:		
Depository institutions	658	1,272
Other deposits	7	3
Deferred credit items	581	505
Interest on Federal Reserve notes due U.S. Treasury	78	—
Interdistrict settlement account	—	495
Accrued benefit costs	65	65
Other liabilities	11	14
Total liabilities	**34,146**	**32,772**
Capital:		
Capital paid-in	1,014	1,065
Surplus	1,014	1,065
Total capital	**2,028**	**2,130**
Total liabilities and capital	**$ 36,174**	**$ 34,902**

The accompanying notes are an integral part of these financial statements.

Statements of Income *(in millions)*

	For the year ended December 31, 2005	For the year ended December 31, 2004
Interest income:		
Interest on U.S. government securities	$ 1,191	$ 963
Interest on investments denominated in foreign currencies	25	22
Total interest income	**1,216**	**985**
Interest expense:		
Interest expense on securities sold under agreements to repurchase	34	13
Net interest income	**1,182**	**972**
Other operating income (loss):		
Income from services	—	61
Compensation received for check services provided	60	—
Reimbursable services to government agencies	55	43
Foreign currency (losses)/gains, net	(243)	101
Other income	5	3
Total other operating income (loss)	**(123)**	**208**
Operating expenses:		
Salaries and other benefits	106	103
Occupancy expense	15	13
Equipment expense	11	13
Assessments by the Board of Governors	50	45
Other expenses	64	48
Total operating expenses	**246**	**222**
Net income prior to distribution	**$ 813**	**$ 958**
Distribution of net income:		
Dividends paid to member banks	$ 65	$ 45
Transferred (from)/to surplus	(51)	338
Payments to U.S. Treasury as interest on Federal Reserve notes	799	575
Total distribution	**$ 813**	**$ 958**

Statements of Changes in Capital *(in millions)*

For the years ended December 31, 2005 and December 31, 2004

	Capital Paid-in	Surplus	Total Capital
Balance at January 1, 2004 (14.5 million shares)	$ 727	$ 727	$ 1,454
Transferred to surplus	—	338	338
Net change in capital stock issued (6.8 million shares)	338	—	338
Balance at December 31, 2004 (21.3 million shares)	$ 1,065	$ 1,065	$ 2,130
Transferred from surplus	—	(51)	(51)
Net change in capital stock redeemed (1.0 million shares)	(51)	—	(51)
Balance at December 31, 2005 (20.3 million shares)	$ 1,014	$ 1,014	$ 2,028

The accompanying notes are an integral part of these financial statements.

Notes to Financial Statements

1. STRUCTURE

The Federal Reserve Bank of Cleveland ("Bank") is part of the Federal Reserve System ("System") and one of the twelve Reserve Banks ("Reserve Banks") created by Congress under the Federal Reserve Act of 1913 ("Federal Reserve Act"), which established the central bank of the United States. The Reserve Banks are chartered by the federal government and possess a unique set of governmental, corporate, and central bank characteristics. The Bank and its branches in Cincinnati and Pittsburgh serve the Fourth Federal Reserve District, which includes Ohio and portions of Kentucky, Pennsylvania, and West Virginia.

In accordance with the Federal Reserve Act, supervision and control of the Bank are exercised by a Board of Directors. The Federal Reserve Act specifies the composition of the Board of Directors for each of the Reserve Banks. Each board is composed of nine members serving three-year terms: three directors, including those designated as Chairman and Deputy Chairman, are appointed by the Board of Governors, and six directors are elected by member banks. Banks that are members of the System include all national banks and any state-chartered banks that apply and are approved for membership in the System. Member banks are divided into three classes according to size. Member banks in each class elect one director representing member banks and one representing the public. In any election of directors, each member bank receives one vote, regardless of the number of shares of Reserve Bank stock it holds.

The System also consists, in part, of the Board of Governors of the Federal Reserve System ("Board of Governors") and the Federal Open Market Committee ("FOMC"). The Board of Governors, an independent federal agency, is charged by the Federal Reserve Act with a number of specific duties, including general supervision over the Reserve Banks. The FOMC is composed of members of the Board of Governors, the president of the Federal Reserve Bank of New York ("FRBNY"), and, on a rotating basis four other Reserve Bank presidents.

2. OPERATIONS AND SERVICES

The System performs a variety of services and operations. Functions include formulating and conducting monetary policy; participating actively in the payments system including large-dollar transfers of funds, automated clearinghouse ("ACH") operations, and check processing; distributing coin and currency; performing fiscal agency functions for the U.S. Treasury and certain federal agencies; serving as the federal government's bank; providing short-term loans to depository institutions; serving the consumer and the community by providing educational materials and information regarding consumer laws; supervising bank holding companies, state member banks, and U.S. offices of foreign banking organizations; and administering other regulations of the Board of Governors. The System also provides certain services to foreign central banks, governments, and international official institutions.

The FOMC, in the conduct of monetary policy, establishes policy regarding domestic open market operations, oversees these operations, and annually issues authorizations and directives to the FRBNY for its execution of transactions. FRBNY is authorized to conduct operations in domestic markets, including direct purchase and sale of U. S. government securities, the purchase of securities under agreements to resell, the sale of securities under agreements to repurchase, and the lending of U.S. government securities. FRBNY executes these open market transactions and holds the resulting securities, with the exception of securities purchased under agreements to resell, in the portfolio known as the System Open Market Account ("SOMA").

In addition to authorizing and directing operations in the domestic securities market, the FOMC authorizes and directs FRBNY to execute operations in foreign markets for major currencies in order to counter disorderly conditions in exchange markets or to meet other needs specified by the FOMC in carrying out the System's central bank responsibilities. The FRBNY is authorized by the FOMC to hold balances of, and to execute spot and forward foreign exchange ("F/X") and securities contracts for nine foreign currencies and to invest such foreign currency holdings ensuring adequate liquidity is maintained. In addition, FRBNY is authorized to maintain reciprocal currency arrangements ("F/X swaps") with two central banks, and "warehouse" foreign currencies for the U.S. Treasury and Exchange Stabilization Fund ("ESF") through the Reserve Banks. In connection with its foreign currency activities, FRBNY may enter into contracts that contain varying degrees of off-balance-sheet market risk, because they represent contractual commitments involving future settlement and counter-party credit risk. The FRBNY controls credit risk by obtaining credit approvals, establishing transaction limits, and performing daily monitoring procedures.

Although Reserve Banks are separate legal entities, in the interests of greater efficiency and effectiveness, they collaborate in the delivery of certain operations and services. The collaboration takes the form of centralized competency centers, operations sites, and product or service offices that have responsibility for the delivery of certain services on behalf of the Reserve Banks. Various operational and management models are used and are supported by service agreements between the Reserve Bank providing the service and the other eleven Reserve Banks. In some cases, costs incurred by a Reserve Bank for services provided to other Reserve Banks are not shared; in other cases, Reserve Banks are billed for services provided to them by another Reserve Bank.

Major services provided on behalf of the System by the Bank, for which the costs were not redistributed to the other Reserve Banks, include: Retail Payments Office, FedImage, Savings Bonds technology, National Check Adjustments, Check 21, National Check Restructure, Cash Automation and Materials Handling Software, Check Automation Services, National Billing Operations, and Audit Application Competency Center.

Beginning in 2005, the Reserve Banks adopted a new management model for providing check services to depository institutions. Under this new model, the Federal Reserve Bank of Atlanta ("FRBA") has the overall responsibility for managing the Reserve Banks' provision of check services and recognizes total System check revenue on its Statements of Income. FRBA compensates the other eleven Reserve Banks for the costs incurred to provide check services. This compensation is reported as "Compensation received for check services provided" in the Statements of Income. If the management model had been in place in 2004, the Bank would have reported $58 million as compensation received for check services provided and $61 million in check revenue would have been reported by FRB Atlanta rather than the Bank.

3. SIGNIFICANT ACCOUNTING POLICIES

Accounting principles for entities with the unique powers and responsibilities of the nation's central bank have not been formulated by the various accounting standard-setting bodies. The Board of Governors has developed specialized accounting principles and practices that it believes are appropriate for the significantly different nature and function of a central bank as compared with the private sector. These accounting principles and practices are documented in the *Financial Accounting Manual for Federal Reserve Banks* ("Financial Accounting Manual"), which is issued by the Board of Governors. All Reserve Banks are required to adopt and apply accounting policies and practices that are consistent with the Financial Accounting Manual and the financial statements have been prepared in accordance with the Financial Accounting Manual.

Differences exist between the accounting principles and practices in the Financial Accounting Manual and those generally accepted in the United States ("GAAP") primarily due to the unique nature of the Bank's powers and responsibilities as part of the nation's central bank. The primary difference is the presentation of all security holdings at amortized cost, rather than using the fair value presentation requirements in accordance with GAAP. Amortized cost more appropriately reflects the Bank's security holdings given its unique responsibility to conduct monetary policy. While the application of current market prices to the securities holdings may result in values substantially above or below their carrying values, these unrealized changes in value would have no direct affect on the quantity of reserves available to the banking system or on the prospects for future Bank earnings or capital. Both the domestic and foreign components of the SOMA portfolio may involve transactions that result in gains or losses when holdings are sold prior to maturity. Decisions regarding security and foreign currency transactions, including their purchase and sale, are motivated by monetary policy objectives rather than profit. Accordingly, market values, earnings, and any gains or losses resulting from the sale of such securities and currencies are incidental to the open market operations and do not motivate its activities or policy decisions.

In addition, the Bank has elected not to present a Statement of Cash Flows because the liquidity and cash position of the Bank are not a primary concern given the Bank's unique powers and responsibilities. A Statement of Cash Flows, therefore, would not provide any additional meaningful information. Other information regarding the Bank's activities is provided in, or may be derived from, the Statements of Condition, Income, and Changes in Capital. There are no other significant differences between the policies outlined in the Financial Accounting Manual and GAAP.

The preparation of the financial statements in conformity with the Financial Accounting Manual requires management to make certain estimates and assumptions that affect the reported amounts of assets and liabilities, disclosure of contingent assets and liabilities at the date of the financial statements, and the reported amounts of income and expenses during the reporting period. Actual results could differ from those estimates. Certain amounts relating to the prior year have been reclassified to conform to the current-year presentation. Unique accounts and significant accounting policies are explained below.

a. Gold and Special Drawing Rights Certificates

The Secretary of the U.S. Treasury is authorized to issue gold and special drawing rights ("SDR") certificates to the Reserve Banks.

Payment for the gold certificates by the Reserve Banks is made by crediting equivalent amounts in dollars into the account established for the U.S. Treasury. These gold certificates held by the Reserve Banks are required to be backed by the gold of the U.S. Treasury. The U.S. Treasury may reacquire the gold certificates at any time and the Reserve Banks must deliver them to the U.S. Treasury. At such time, the U.S. Treasury's account is charged, and the Reserve Banks' gold certificate accounts are lowered. The value of gold for purposes of backing the gold certificates is set by law at $42 2/9 a fine troy ounce. The Board of Governors allocates the gold certificates among Reserve Banks once a year based on the average Federal Reserve notes outstanding in each Reserve Bank.

Special drawing rights ("SDRs") are issued by the International Monetary Fund ("Fund") to its members in proportion to each member's quota in the Fund at the time of issuance. SDRs serve as a supplement to international monetary reserves and may be transferred from one national monetary authority to another. Under the law providing for United States participation in the SDR system, the Secretary of the U.S. Treasury is authorized to issue SDR certificates, somewhat like gold certificates, to the Reserve Banks. At such time, equivalent amounts in dollars are credited to the account established for the U.S. Treasury, and the Reserve Banks' SDR certificate accounts are increased. The Reserve Banks are required to purchase SDR certificates, at the direction of the U.S. Treasury, for the purpose of financing SDR acquisitions or for financing exchange stabilization operations. At the time SDR transactions occur, the Board of Governors allocates SDR certificate transactions among Reserve Banks based upon Federal Reserve notes outstanding in each District at the end of the preceding year. There were no SDR transactions in 2005 or 2004.

b. Loans to Depository Institutions

All depository institutions that maintain reservable transaction accounts or nonpersonal time deposits, as defined in regulations issued by the Board of Governors, have borrowing privileges at the discretion of the Reserve Bank. Borrowers execute certain lending agreements and deposit sufficient collateral before credit is extended. Loans are evaluated for collectibility. If loans were ever deemed to be uncollectible, an appropriate reserve would be established. Interest is accrued using the applicable discount rate established at least every fourteen days by the Board of Directors of the Reserve Bank, subject to review by the Board of Governors. There were no outstanding loans to depository institutions at December 31, 2005 and 2004.

c. U.S. Government Securities and Investments Denominated in Foreign Currencies

U.S. government securities and investments denominated in foreign currencies comprising the SOMA are recorded at cost, on a settlement-date basis, and adjusted for amortization of premiums or accretion of discounts on a straight-line basis. Interest income is accrued on a straight-line basis. Gains and losses resulting from sales of securities are determined by specific issues based on average cost. Foreign-currency-denominated assets are revalued daily at current foreign currency market exchange rates in order to report these assets in U.S. dollars. Realized and unrealized gains and losses on investments denominated in foreign currencies are reported as "Foreign currency gains (losses), net."

Activity related to U.S. government securities, including the related premiums, discounts, and realized and unrealized gains and losses, is allocated to each Reserve Bank on a percentage basis derived from an annual settlement of interdistrict clearings that occurs in April of each year. The settlement equalizes

Reserve Bank gold certificate holdings to Federal Reserve notes outstanding in each District. Activity related to investments in foreign-currency-denominated assets is allocated to each Reserve Bank based on the ratio of each Reserve Bank's capital and surplus to aggregate capital and surplus at the preceding December 31.

d. U.S. Government Securities Sold Under Agreements to Repurchase and Securities Lending

Securities sold under agreements to repurchase are accounted for as financing transactions and the associated interest expense is recognized over the life of the transaction. These transactions are carried in the Statements of Condition at their contractual amounts and the related accrued interest is reported as a component of "Other liabilities."

U.S. government securities held in the SOMA are lent to U.S. government securities dealers and to banks participating in U.S. government securities clearing arrangements in order to facilitate the effective functioning of the domestic securities market. Securities-lending transactions are fully collateralized by other U.S. government securities and the collateral taken is in excess of the market value of the securities loaned. The FRBNY charges the dealer or bank a fee for borrowing securities and the fees are reported as a component of "Other income" in the Statements of Income.

Activity related to U.S. government securities sold under agreements to repurchase and securities lending is allocated to each Reserve Bank on a percentage basis derived from the annual settlement of interdistrict clearings. Securities purchased under agreements to resell are allocated to FRBNY and not to the other Banks.

e. Foreign Currency Swaps and Warehousing

F/X swap arrangements are contractual agreements between two parties to exchange specified currencies, at a specified price, on a specified date. The parties agree to exchange their currencies up to a pre-arranged maximum amount and for an agreed-upon period of time (up to twelve months), at an agreed-upon interest rate. These arrangements give the FOMC temporary access to the foreign currencies it may need to intervene to support the dollar and give the counterparty temporary access to dollars it may need to support its own currency. Drawings under the F/X swap arrangements can be initiated by either FRBNY or the counterparty (the drawer) and must be agreed to by the drawee. The F/X swaps are structured so that the party initiating the transaction bears the exchange rate risk upon maturity. FRBNY will generally invest the foreign currency received under an F/X swap in interest-bearing instruments.

Warehousing is an arrangement under which the FOMC agrees to exchange, at the request of the U.S. Treasury, U.S. dollars for foreign currencies held by the U.S. Treasury or ESF over a limited period of time. The purpose of the warehousing facility is to supplement the U.S. dollar resources of the U.S. Treasury and ESF for financing purchases of foreign currencies and related international operations.

Foreign currency swaps and warehousing agreements are revalued daily at current market exchange rates. Activity related to these agreements, with the exception of the unrealized gains and losses resulting from the daily revaluation, is allocated to each Reserve Bank based on the ratio of each Reserve Bank's capital and surplus to aggregate capital and surplus at the preceding December 31. Unrealized gains and losses resulting from the daily revaluation are allocated to FRBNY and not to the other Reserve Banks.

f. Bank Premises, Equipment, and Software

Bank premises and equipment are stated at cost less accumulated depreciation. Depreciation is calculated on a straight-line basis over estimated useful lives of assets ranging from one to fifty years. Major alterations, renovations, and improvements are capitalized at cost as additions to the asset accounts and are amortized over the remaining useful life of the asset. Maintenance, repairs, and minor replacements are charged to operating expense in the year incurred. Capitalized assets including software, building, leasehold improvements, furniture, and equipment are impaired when it is determined that the net realizable value is significantly less than book value and is not recoverable.

Costs incurred for software, either developed internally or acquired for internal use, during the application development stage are capitalized based on the cost of direct services and materials associated with designing, coding, installing, or testing software. Capitalized software costs are amortized on a straight-line basis over the estimated useful lives of the software applications, which range from one to five years.

g. Interdistrict Settlement Account

At the close of business each day, each Reserve Bank assembles the payments due to or from other Reserve Banks as a result of the day's transactions that involve depository institution accounts held by other Districts. Such transactions may include funds settlement, check clearing, and ACH operations. The cumulative net amount due to or from the other Reserve Banks is reflected in the "Interdistrict settlement account" in the Statements of Condition.

h. Federal Reserve Notes

Federal Reserve notes are the circulating currency of the United States. These notes are issued through the various Federal Reserve agents (the Chairman of the Board of Directors of each Reserve Bank) to the Reserve Banks upon deposit with such agents of certain classes of collateral security, typically U.S. government securities. These notes are identified as issued to a specific Reserve Bank. The Federal Reserve Act provides that the collateral security tendered by the Reserve Bank to the Federal Reserve agent must be equal to the sum of the notes applied for by such Reserve Bank.

Assets eligible to be pledged as collateral security include all Bank assets. The collateral value is equal to the book value of the collateral tendered, with the exception of securities, whose collateral value is equal to the par value of the securities tendered. The par value of securities pledged for securities sold under agreements to repurchase is deducted.

The Board of Governors may, at any time, call upon a Reserve Bank for additional security to adequately collateralize the Federal Reserve notes. To satisfy the obligation to provide sufficient collateral for outstanding Federal Reserve notes, the Reserve Banks have entered into an agreement that provides for certain assets of the Reserve Banks to be jointly pledged as collateral for the Federal Reserve notes of all Reserve Banks. In the event that this collateral is insufficient, the Federal Reserve Act provides that Federal Reserve notes become a first and paramount lien on all the assets of the Reserve Banks. Finally, as obligations of the United States, Federal Reserve notes are backed by the full faith and credit of the United States government.

The "Federal Reserve notes outstanding, net" account represents the Bank's Federal Reserve notes outstanding, reduced by the currency issued to the Bank but not in circulation, of $5,081 million and $5,408 million at December 31, 2005 and 2004, respectively.

i. Items in Process of Collection and Deferred Credit Items

The balance in the "Items in process of collection" line in the Statements of Condition primarily represents amounts attributable to checks that have been deposited for collection by the payee depository institution and, as of the balance sheet date, have not yet been collected from the payor depository institution. Deferred credit items are the counterpart liability to items in process of collection, and the amounts in this account arise from deferring credit for deposited items until the amounts are collected. The balances in both accounts can fluctuate and vary significantly from day to day.

j. Capital Paid-in

The Federal Reserve Act requires that each member bank subscribe to the capital stock of the Reserve Bank in an amount equal to 6 percent of the capital and surplus of the member bank. These shares are nonvoting with a par value of $100 and may not be transferred or hypothecated. As a member bank's capital and surplus changes, its holdings of Reserve Bank stock must be adjusted. Currently, only one-half of the subscription is paid-in and the remainder is subject to call. By law, each Bank is required to pay each member bank an annual dividend of 6 percent on the paid-in capital stock. This cumulative dividend is paid semiannually. A member bank is liable for Reserve Bank liabilities up to twice the par value of stock subscribed by it.

k. Surplus

The Board of Governors requires Reserve Banks to maintain a surplus equal to the amount of capital paid-in as of December 31. This amount is intended to provide additional capital and reduce the possibility that the Reserve Banks would be required to call on member banks for additional capital. Pursuant to Section 16 of the Federal Reserve Act, Reserve Banks are required by the Board of Governors to transfer to the U.S. Treasury as interest on Federal Reserve notes excess earnings, after providing for the costs of operations, payment of dividends, and reservation of an amount necessary to equate surplus with capital paid-in.

In the event of losses or an increase in capital paid-in at a Reserve Bank, payments to the U.S. Treasury are suspended and earnings are retained until the surplus is equal to the capital paid-in. Weekly payments to the U.S. Treasury may vary significantly.

In the event of a decrease in capital paid-in, the excess surplus, after equating capital paid-in and surplus at December 31, is distributed to the U.S. Treasury in the following year. This amount is reported as a component of "Payments to U.S. Treasury as interest on Federal Reserve notes."

l. Income and Costs related to U.S. Treasury Services

The Bank is required by the Federal Reserve Act to serve as fiscal agent and depository of the United States. By statute, the Department of the Treasury is permitted, but not required, to pay for these services.

m. Assessments by the Board of Governors

The Board of Governors assesses the Reserve Banks to fund its operations based on each Reserve Bank's capital and surplus balances. The Board of Governors also assesses each Reserve Bank for the expenses incurred for the U.S. Treasury to issue and retire Federal Reserve notes based on each Reserve Bank's share of the number of notes comprising the System's net liability for Federal Reserve notes on December 31 of the previous year.

n. Taxes

The Reserve Banks are exempt from federal, state, and local taxes, except for taxes on real property. The Bank's real property taxes were $2 million for each of the years ended December 31, 2005 and 2004, and are reported as a component of "Occupancy expense."

o. Restructuring Charges

In 2003, the System began the restructuring of several operations, primarily check, cash, and U.S. Treasury services. The restructuring included streamlining the management and support structures, reducing staff, decreasing the number of processing locations, and increasing processing capacity in the remaining locations. These restructuring activities continued in 2004 and 2005.

Footnote 10 describes the restructuring and provides information about the Bank's costs and liabilities associated with employee separations and contract terminations. The costs associated with the write-down of certain Bank assets are discussed in footnote 6. Costs and liabilities associated with enhanced pension benefits in connection with the restructuring activities for all Reserve Banks are recorded on the books of the FRBNY and those associated with enhanced post-retirement benefits are discussed in footnote 9.

4. U.S. GOVERNMENT SECURITIES, SECURITIES SOLD UNDER AGREEMENTS TO REPURCHASE, AND SECURITIES LENDING

The FRBNY, on behalf of the Reserve Banks, holds securities bought outright in the SOMA. The Bank's allocated share of SOMA balances was approximately 4.225 percent and 4 273 percent at December 31, 2005 and 2004, respectively.

The Bank's allocated share of U.S. Government securities, net, held in the SOMA at December 31, was as follows (in millions):

	2005	2004
Par value:		
U.S. government:		
Bills	$ 11,460	$ 11,237
Notes	16,058	15,418
Bonds	3,921	4,017
Total par value	31,439	30,672
Unamortized premiums	372	402
Unaccreted discounts	(119)	(70)
Total allocated to Bank	$ 31,692	$ 31,004

The total of the U.S. government securities, net held in the SOMA was $750,202 million and $725,584 million at December 31, 2005 and 2004, respectively.

At December 31, 2005 and 2004, the total contract amount of securities sold under agreements to repurchase was $30,505 million and $30,783 million, respectively, of which $1,289 million and $1,315 million, were allocated to the Bank. The total par value of the SOMA securities pledged for securities sold under agreements to repurchase at December 31, 2005 and 2004 was $30,559 million and $30,808 million, respectively, of which $1,291 million and $1,316 million was allocated to the Bank.

The maturity distribution of U.S. government securities bought outright and securities sold under agreements to repurchase, that were allocated to the Bank at December 31, 2005, was as follows (in millions):

Maturities of Securities Held	U.S. Government Securities (Par value)	Securities Sold Under Agreements to Repurchase (Contract amount)
Within 15 days	$ 1,732	$ 1,289
16 days to 90 days	7,277	—
91 days to 1 year	7,870	—
Over 1 year to 5 years	8,903	—
Over 5 years to 10 years	2,395	—
Over 10 years	3,262	—
Total	$ 31,439	$ 1,289

At December 31, 2005 and 2004, U.S. government securities with par values of $3,776 million and $6,609 million, respectively, were loaned from the SOMA, of which $160 million and $282 million, respectively, were allocated to the Bank.

5. INVESTMENTS DENOMINATED IN FOREIGN CURRENCIES

The FRBNY, on behalf of the Reserve Banks, holds foreign currency deposits with foreign central banks and the Bank for International Settlements and invests in foreign government debt instruments. Foreign government debt instruments held include both securities bought outright and securities purchased under agreements to resell. These investments are guaranteed as to principal and interest by the foreign governments.

The Bank's allocated share of investments denominated in foreign currencies was approximately 9.043 percent and 8 220 percent at December 31, 2005 and 2004, respectively.

The Bank's allocated share of investments denominated in foreign currencies, including accrued interest, valued at current foreign currency market exchange rates at December 31, was as follows (in millions):

	2005	2004
European Union Euro:		
Foreign currency deposits	$ 491	$ 500
Securities purchased under agreements to resell	174	176
Government debt instruments	322	324
Japanese Yen:		
Foreign currency deposits	237	127
Government debt instruments	488	630
Total	$ 1,712	$ 1,757

Total System investments denominated in foreign currencies were $18,928 million and $21,368 million at December 31, 2005 and 2004, respectively.

The maturity distribution of investments denominated in foreign currencies which were allocated to the Bank at December 31, 2005, was as follows (in millions):

Maturities of Investments Denominated in Foreign Currencies	European Euro	Japanese Yen	Total
Within 15 days	$ 306	$ 237	$ 543
16 days to 90 days	233	61	294
91 days to 1 year	189	91	280
Over 1 year to 5 years	258	336	594
Over 5 years to 10 years	1	—	1
Over 10 years	—	—	—
Total	$ 987	$ 725	$ 1,712

At December 31, 2005 and 2004, there were no open or outstanding foreign exchange contracts.

At December 31, 2005 and 2004, the warehousing facility was $5,000 million, with no balance outstanding.

6. BANK PREMISES, EQUIPMENT, AND SOFTWARE

A summary of bank premises and equipment at December 31 is as follows (in millions):

	Useful Life Range (in Years)	2005	2004
Bank premises and equipment:			
Land	N/A	$ 8	$ 7
Buildings	1–43	170	163
Building machinery and equipment	1–20	49	48
Construction in progress	N/A	3	6
Furniture and equipment	1–9	70	68
Subtotal		$ 300	$ 292
Accumulated depreciation		(115)	(109)
Bank premises and equipment, net		$ 185	$ 183
Depreciation expense, for the years ended		$ 11	$ 11

The Bank leases space to outside tenants with lease terms ranging from one to nine years. Rental income from such leases was $1 million for each of the years ended December 31, 2005 and 2004. Future minimum lease payments under noncancelable agreements in existence at December 31, 2005, were (in millions):

2006	$ 1
2007	1
2008	1
2009	1
2010	1
Thereafter	3
	$ 8

The Bank has capitalized software assets, net of amortization, of $39 million for each of the years ended December 31, 2005 and 2004. Amortization expense was $12 million and $8 million for the years ended December 31, 2005 and 2004, respectively. Capitalized software assets are reported as a component of "Other assets" and related amortization is reported as a component of "Other expenses." Obsolete software assets of $1 million were written off for each of the years ended December 31, 2005 and 2004. The majority of the write offs were reimbursed by the Department of the Treasury.

Assets impaired as a result of the Bank's restructuring plan, as discussed in footnote 10, include building, leasehold improvements, furniture, and equipment. Asset impairment losses of $2 million for the period ending December 31, 2004, were determined using fair values based on quoted market values or other valuation techniques and are reported as a component of "Other expenses." The Bank had no impairment losses in 2005.

7. COMMITMENTS AND CONTINGENCIES

At December 31, 2005, the Bank was obligated under noncancelable leases for premises and equipment with terms ranging from one to approximately two years. These leases provide for increased rental payments based upon increases in real estate taxes, operating costs, or selected price indices.

Rental expense under operating leases for certain operating facilities, warehouses, and data processing and office equipment (including taxes, insurance and maintenance when included in rent), net of sublease rentals, was $1 million for each of the years ended December 31, 2005 and 2004. Certain of the Bank's leases have options to renew.

Future minimum rental payments under noncancelable operating leases and capital leases, net of sublease rentals, with terms of one year or more, at December 31, 2005, were not material.

At December 31, 2005, the Bank, acting on its own behalf, had other commitments and long-term obligations extending through the year 2010 with a remaining amount of $14 million. As of December 31, 2005, commitments of $50 million were recognized. Purchases of $22 million and $18 million were made against these commitments during 2005 and 2004, respectively. These commitments represent Electronic Treasury Financial Services, facilities-related expenditures, and Cash and Check transportation and have variable and fixed components. The variable portion of the commitments is primarily for Cash and Check transportation. The fixed payments for the next five years under these commitments are (in millions):

	Fixed Commitment
2006	$ 6.6
2007	2.1
2008	2.0
2009	0.3
2010	0.1

At December 31, 2005, the Bank, acting on behalf of the Reserve Banks, had contractual commitments extending through the year 2012 totaling $41 million. As of December 31, 2005, commitments of $54 million were recognized. Purchases of $16 million and $7 million were made against these commitments during 2005 and 2004, respectively. It is estimated that the Bank's allocated share of these commitments will be $8 million. These commitments represent Check software and hardware license and maintenance fees and have only fixed components. The fixed payments for the next five years under these commitments are (in millions):

	Fixed Commitment
2006	$ 12.7
2007	12.3
2008	10.0
2009	5.9
2010	0.1

Under the Insurance Agreement of the Federal Reserve Banks, each Reserve Bank has agreed to bear, on a per incident basis, a pro rata share of losses in excess of one percent of the capital paid-in of the claiming Reserve Bank, up to 50 percent of the total capital paid-in of all Reserve Banks. Losses are borne in the ratio that a Reserve Bank's capital paid-in bears to the total capital paid-in of all Reserve Banks at the beginning of the calendar year in which the loss is shared. No claims were outstanding under such agreement at December 31, 2005 or 2004.

The Bank is involved in certain legal actions and claims arising in the ordinary course of business. Although it is difficult to predict the ultimate outcome of these actions, in management's opinion, based on discussions with counsel, the aforementioned litigation and claims will be resolved without material adverse effect on the financial position or results of operations of the Bank.

8. RETIREMENT AND THRIFT PLANS

Retirement Plans

The Bank currently offers three defined benefit retirement plans to its employees, based on length of service and level of compensation. Substantially all of the Bank's employees participate in the Retirement Plan for Employees of the Federal Reserve System ("System Plan"). Employees at certain compensation levels participate in the Benefit Equalization Retirement Plan ("BEP") and certain Bank officers participate in the Supplemental Employee Retirement Plan ("SERP").

The System Plan is a multi-employer plan with contributions fully funded by participating employers. Participating employers are the Federal Reserve Banks, the Board of Governors of the Federal Reserve System, and the Office of Employee Benefits of the Federal Reserve System. No separate accounting is maintained of assets contributed by the participating employers. The FRBNY acts as a sponsor of the System Plan and the costs associated with the Plan are not redistributed to other participating employers. The Bank's benefit obligation and net pension costs for the BEP and the SERP at December 31, 2005 and 2004, and for the years then ended, are not material.

Thrift Plan

Employees of the Bank may also participate in the defined contribution Thrift Plan for Employees of the Federal Reserve System ("Thrift Plan"). The Bank's Thrift Plan contributions totaled $4 million and $3 million for the years ended December 31, 2005 and 2004, respectively, and are reported as a component of "Salaries and other benefits." The Bank matches employee contributions based on a specified formula. For the years ended December 31, 2005 and 2004, the Bank matched 80 percent on the first 6 percent of employee contributions for employees with less than five years of service and 100 percent on the first 6 percent of employee contributions for employees with five or more years of service.

9. POSTRETIREMENT BENEFITS OTHER THAN PENSIONS AND POSTEMPLOYMENT BENEFITS

Postretirement Benefits other than Pensions

In addition to the Bank's retirement plans, employees who have met certain age and length of service requirements are eligible for both medical benefits and life insurance coverage during retirement.

The Bank funds benefits payable under the medical and life insurance plans as due and, accordingly, has no plan assets.

Following is a reconciliation of beginning and ending balances of the benefit obligation (in millions):

	2005	2004
Accumulated postretirement benefit obligation at January 1	$ 66.3	$ 56.1
Service cost-benefits earned during the period	1.6	1.8
Interest cost of accumulated benefit obligation	3.1	4.1
Actuarial (gain) loss	(9.0)	20.2
Special termination (gain) loss	—	0.1
Contributions by plan participants	0.3	0.2
Benefits paid	(3.1)	(2.8)
Plan amendments	—	(13.4)
Accumulated postretirement benefit obligation at December 31	$ 59.2	$ 66.3

At December 31, 2005 and 2004, the weighted-average discount rate assumptions used in developing the postretirement benefit obligation were 5.50 percent and 5.75 percent, respectively.

Discount rates reflect yields available on high quality corporate bonds that would generate the cash flows necessary to pay the plan's benefits when due.

Following is a reconciliation of the beginning and ending balance of the plan assets, the unfunded postretirement benefit obligation, and the accrued postretirement benefit costs (in millions):

	2005	2004
Fair value of plan assets at January 1	$ —	$ —
Actual return on plan assets	—	—
Contributions by the employer	2.8	2.6
Contributions by plan participants	0.3	0.2
Benefits paid	(3.1)	(2.8)
Fair value of plan assets at December 31	$ —	$ —
Unfunded postretirement benefit obligation	$ 59.2	$ 66.3
Unrecognized prior service cost	10.2	12.5
Unrecognized net actuarial (loss)	(13.7)	(23.1)
Accrued postretirement benefit costs	$ 55.7	$ 55.7

Accrued postretirement benefit costs are reported as a component of "Accrued benefit costs."

For measurement purposes, the assumed health care cost trend rates at December 31 are as follows:

	2005	2004
Health care cost trend rate assumed for next year	9.00%	9.00%
Rate to which the cost trend rate is assumed to decline (the ultimate trend rate)	5.00%	4.75%
Year that the rate reaches the ultimate trend rate	2011	2011

Assumed health care cost trend rates have a significant effect on the amounts reported for health care plans. A one percentage point change in assumed health care cost trend rates would have the following effects for the year ended December 31, 2005 (in millions):

	One Percentage Point Increase	One Percentage Point Decrease
Effect on aggregate of service and interest cost components of net periodic postretirement benefit costs	$ 0.8	$ (0.6)
Effect on accumulated postretirement benefit obligation	7.9	(6.5)

The following is a summary of the components of net periodic postretirement benefit costs for the years ended December 31 (in millions):

	2005	2004
Service cost–benefits earned during the period	$ 1.6	$ 1.8
Interest cost of accumulated benefit obligation	3.1	4.1
Amortization of prior service cost	(2.3)	(0.6)
Recognized net actuarial loss	0.4	0.8
Total periodic expense	$ 2.8	$ 6.1
Curtailment (gain)	—	(1.1)
Special termination loss	—	0.1
Net periodic postretirement benefit costs	$ 2.8	$ 5.1

Net postretirement benefit costs are actuarially determined using a January 1 measurement date. At January 1, 2005 and 2004, the weighted-average discount rate assumptions used to determine net periodic postretirement benefit costs were 5.75 percent and 6 25 percent, respectively.

Net periodic postretirement benefit costs are reported as a component of "Salaries and other benefits."

A plan amendment that modified the credited service period eligibility requirements created curtailment gains in 2004. The recognition of special termination losses is primarily the result of enhanced retirement benefits provided to employees during the restructuring described in footnote 10.

The Medicare Prescription Drug, Improvement and Modernization Act of 2003 established a prescription drug benefit under Medicare ("Medicare Part D") and a federal subsidy to sponsors of retiree health care benefit plans that provide benefits that are at least actuarially equivalent to Medicare Part D. The benefits provided by the Bank's plan to certain participants are at least actuarially equivalent to the Medicare Part D prescription drug benefit. The estimated effects of the subsidy, retroactive to January 1, 2004, are reflected in actuarial loss in the accumulated postretirement benefit obligation and net periodic postretirement benefit costs.

Following is a summary of expected benefit payments (in millions):

	Without Subsidy	With Subsidy
2006	$ 3.0	$ 2.7
2007	3.1	2.8
2008	3.3	2.9
2009	3.4	3.0
2010	3.5	3.1
2011–2015	20.2	17.7
Total	$ 36.5	$ 32.2

Postemployment Benefits

The Bank offers benefits to former or inactive employees. Postemployment benefit costs are actuarially determined using a December 31, 2005, measurement date and include the cost of medical and dental insurance, survivor income, disability benefits, and self-insured workers' compensation expenses. The accrued postemployment benefit costs recognized by the Bank at December 31, 2005 and 2004, were $8.7 million and $8.6 million, respectively. This cost is included as a component of "Accrued benefit costs." Net periodic postemployment benefit costs included in 2005 and 2004 operating expenses were $1 million and $3 million, respectively and are recorded as a component of "Salaries and other benefits."

10. BUSINESS RESTRUCTURING CHARGES

In 2003, the Bank announced plans for restructuring to streamline operations and reduce costs, including consolidation of Check operations and staff reductions in various functions of the Bank. In 2004 and 2005, additional consolidation and restructuring initiatives were announced in the Check operations, Check Automation Services, and Marketing. These actions resulted in the following business restructuring charges (in millions):

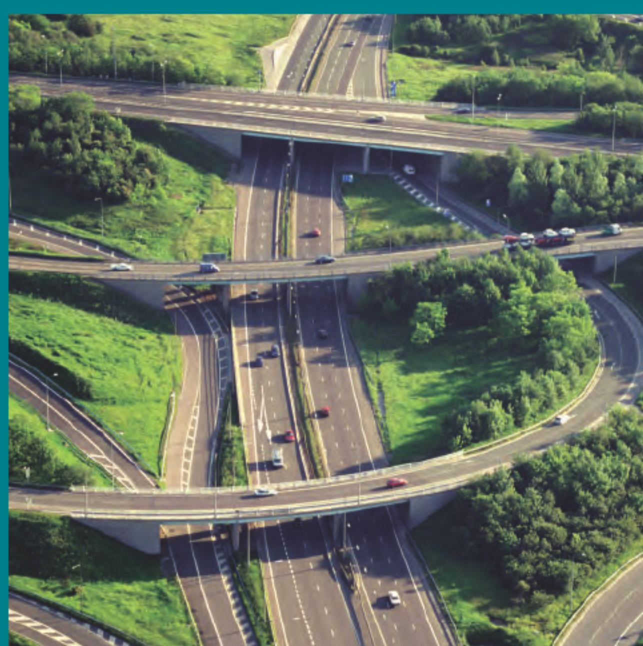
	Total Estimated Costs	Accrued Liability 12/31/2004	Total Charges	Total Paid	Accrued Liability 12/31/2005
Employee separation	$ 1.1	$ 1.2	$ —	$ 0.3	$ 0.9

Employee separation costs are primarily severance costs related to identified staff reductions of approximately 70, including 16 staff reductions related to restructuring announced in 2004. These costs are reported as a component of "Salaries and other benefits." Contract termination costs include the charges resulting from terminating existing lease and other contracts and are shown as a component of "Other expenses."

Restructuring costs associated with the write-downs of certain Bank assets, including software, buildings, leasehold improvements, furniture, and equipment are discussed in footnote 6. Costs associated with enhanced pension benefits for all Reserve Banks are recorded on the books of the FRBNY as discussed in footnote 8. Costs associated with enhanced postretirement benefits are disclosed in footnote 9.

Future costs associated with the announced restructuring plans are not material.

The Bank anticipates substantially completing its announced plans by March 2006.



National Road, 1941

Concrete began to surpass brick and dirt as the preferred road-surface material in 1912, but it wasn't until the Federal Highway Act of 1938 that an interstate highway system was considered, proposed by President Roosevelt as a way of providing jobs. The goal of the act was to study the feasibility of a national, six-route, toll-road network.

Superhighways: An American Icon

The Dwight D. Eisenhower System of Interstate and Defense Highways has over 40,000 miles of interstates, which represent 1 percent of our nation's total road length, yet carry over 20 percent of its traffic. There is hardly one aspect of American society that has not been affected by the interstates.

Officers and Consultants *(as of December 31, 2005)*

Sandra Pianalto
President and Chief Executive Officer

R. Chris Moore
First Vice President and Chief Operating Officer

Andrew C. Burkle, Jr.
Senior Vice President
Supervision and Regulation, Credit Risk Management, Statistics and Analysis

Lawrence Cuy
Senior Vice President
Financial Management Services, Strategic Planning, Information Technology, Risk Management

Robert W. Price
Senior Vice President
Retail Payments Office, National Check Automation and Operations, National Product Development

Susan G. Schueller
Senior Vice President and General Auditor
Audit

Samuel D. Smith
Senior Vice President
Cash, Treasury Retail Securities, Facilities, Information Security, Protection, Business Continuity, eGovernment, Payments System Research

Mark S. Sniderman
Senior Vice President and Director of Research
Research, Economic Policy and Strategy

Peggy A. Velimesis
Senior Vice President
Human Resources, Payroll, Internal Communications, Quality Process, EEO Officer

Andrew W. Watts
Senior Vice President and General Counsel
Legal, Ethics Officer

David E. Altig
Vice President and Associate Director of Research
Research

Douglas A. Banks
Vice President and Consumer Affairs Officer
Supervision and Regulation

Raymond L. Brinkman
Vice President
Treasury Retail Securities

Michael F. Bryan
Vice President and Economist
Research

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Vice President and Community Affairs Officer
Community Affairs

Cheryl L. Davis
Vice President and Corporate Secretary
Community Affairs, Public Information, Office of the Corporate Secretary

William D. Fosnight
Vice President and Associate General Counsel
Legal

Barbara B. Henshaw
Vice President
Cincinnati Location Officer, Protection, Business Continuity

Suzanne M. Howe
Vice President
eGovernment Operations, Treasury Electronic Check Processing

David P. Jager
Vice President
eGovernment

Stephen H. Jenkins
Vice President
Supervision and Regulation

Jon C. Jeswald
Vice President
Retail Payments Office

Rayford P. Kalich
Vice President
Accounting, Budget Procurement, Strategic Planning, Risk Management

Stephen J. Ong
Vice President
Credit Risk Management, Statistics and Analysis

Terrence J. Roth
Vice President
Retail Payments Office, Check Products

Robert B. Schaub
Vice President
Pittsburgh Location Officer, Protection, Business Continuity

Officers and Consultants *(as of December 31, 2005)*

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Vice President
Supervision and Regulation

James B. Thomson
Vice President and Economist
Research

Anthony Turcinov
Vice President
Check Operations, Check Adjustments

Jeffrey R. Van Treese
Vice President
Cincinnati Check Operations

Lisa M. Vidacs
Vice President
Cash Operations

Darell R. Wittrup
Vice President
Accounting, System Billing

Kelly A. Banks
Assistant Vice President and Public Information Officer
Public Information, Communication Support, Learning Center

Tracy L. Conn
Assistant Vice President
Supervision and Regulation

Stephen J. Geers
Assistant Vice President
Check Consolidation

Patrick J. Geyer
Assistant Vice President
eGovernment Operations

Kenneth J. Good
Assistant Vice President
Check Adjustments, Image Services System Operations

Felix Harshman
Assistant Vice President
Accounting, Budget

Joseph G. Haubrich
Consultant and Economist
Research

Amy J. Heinl
Assistant Vice President
Treasury Retail Securities

Paul E. Kaboth
Assistant Vice President
Supervision and Regulation

Kenneth E. Kennard
Assistant Vice President
Protection

Susan M. Kenney
Assistant Vice President
eGovernment Technical Support, Pay.gov

Dean A. Longo
Consultant
Information Technology

Martha Maher
Assistant Vice President
Retail Payments Office

Mark S. Meder
Assistant Vice President
Supervision and Regulation

James J. Miklich
Assistant Vice President
Check Automation Services

Anthony V. Notaro
Assistant Vice President
Facilities

James W. Rakowsky
Assistant Vice President
Cleveland Facilities

Robin R. Ratliff
Assistant Vice President and Assistant Corporate Secretary
Office of the Corporate Secretary

John P. Robins
Consultant
Supervision and Regulation

Elizabeth J. Robinson
Assistant Vice President
Human Resources

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Check Automation Services

Mark E. Schweitzer
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Research

Jerome J. Schwing
Assistant Vice President
Cincinnati Check Operations

James P. Slivka
Assistant Vice President
Information Systems Audit Function, Audit Application Competency Center

Diana C. Starks
Assistant Vice President
Information Technology Governance System Initiative

Henry P. Trolio
Assistant Vice President
Information Technology

Michael Vangelos
Assistant Vice President
Information Security, Business Continuity

Nadine M. Wallman
Assistant Vice President
Supervision and Regulation

Federal Reserve Banks each have a board of nine directors. Directors supervise the Bank's budget and operations, make recommendations on the primary credit rate, and, with the Board of Governors' approval, appoint the Bank's president, first vice president, and officers.

Class A directors are elected by and represent the interests of Fourth District member banks. Class B directors also are elected by member banks but represent the public interests of agriculture, commerce, industry, services, labor, and consumers. Class C directors are selected by the Board of Governors and also represent these public interests.

Directors serve for three years. Two Class C directors are designated by the Board of Governors as chairman and deputy chairman of the board. Directorships generally are limited to two successive terms to ensure that the individuals who serve the Federal Reserve System represent a diversity of backgrounds and experience.

The Cincinnati and Pittsburgh branch offices each have a board of seven directors who serve three-year terms. Board members are appointed by the Federal Reserve Bank of Cleveland and the Board of Governors.

Cleveland Board of Directors *(as of December 31, 2005)*

Robert W. Mahoney
Chairman
Retired Chairman and Chief Executive Officer
Diebold, Incorporated
North Canton, Ohio

Charles E. Bunch
Deputy Chairman
Chairman and Chief Executive Officer
PPG Industries, Inc.
Pittsburgh, Pennsylvania

Phillip R. Cox
President and Chief Executive Officer
Cox Financial Corporation
Cincinnati, Ohio

Tanny Crane
President and Chief Executive Officer
Crane Group Company
Columbus, Ohio

V. Ann Hailey
Executive Vice President and Chief Financial Officer
Limited Brands
Columbus, Ohio

Martin G. McGuinn
Federal Advisory Council Representative
Chairman and Chief Executive Officer
Mellon Financial Corporation
Pittsburgh, Pennsylvania

Henry L. Meyer III
Chairman and Chief Executive Officer
KeyCorp
Cleveland, Ohio

Les C. Vinney
President and Chief Executive Officer
STERIS Corporation
Mentor, Ohio

Bick Weissenrieder
Chairman and Chief Executive Officer
Hocking Valley Bank
Athens, Ohio

Stephen P. Wilson
President and Chief Executive Officer
Lebanon Citizens National Bank
Lebanon, Ohio

(l–r): Charles E. Bunch, Stephen P. Wilson, Bick Weissenrieder, V. Ann Hailey, Robert W. Mahoney, Henry L. Meyer III, Phillip R. Cox, Tanny Crane, and Les C. Vinney.

Cincinnati Board of Directors *(as of December 31, 2005)*

James M. Anderson
Chairman
President and Chief Executive Officer
Cincinnati Children's Hospital Medical Center
Cincinnati, Ohio

James H. Booth
President
Czar Coal Corporation
Lovely, Kentucky

Herbert R. Brown
Senior Vice President
Western & Southern Financial Group
Cincinnati, Ohio

Glenn D. Leveridge
President, Lexington Market
JPMorgan Chase Bank
Lexington, Kentucky

Charlotte W. Martin
President and Chief Executive Officer
Great Lakes Bankers Bank
Gahanna, Ohio

V. Daniel Radford
Executive Secretary–Treasurer
Cincinnati AFL–CIO Labor Council
Cincinnati, Ohio

Charles Whitehead
Retired President
Ashland Inc. Foundation
Covington, Kentucky

(l–r): Herbert R. Brown, James H. Booth, James M. Anderson, V. Daniel Radford, Charles Whitehead, Charlotte W. Martin, and Glenn D. Leveridge.

Pittsburgh Board of Directors *(as of December 31, 2005)*

Roy W. Haley
Chairman
Chairman and Chief Executive Officer
WESCO International, Inc.
Pittsburgh, Pennsylvania

Robert O. Agbede
President and Chief Executive Officer
ATS–Chester Engineers, Inc.
Pittsburgh, Pennsylvania

Michael J. Hagan
President and Chief Executive Officer
Iron and Glass Bank
Pittsburgh, Pennsylvania

James I. Mitnick
Senior Vice President
Turner Construction Company
Pittsburgh, Pennsylvania

Kristine N. Molnar
Executive Vice President
WesBanco Bank, Inc.
Wheeling, West Virginia

Georgiana N. Riley
President and Chief Executive Officer
TIGG Corporation
Bridgeville, Pennsylvania

(l–r): Robert O. Agbede, Georgiana N. Riley, James I. Mitnick, Roy W. Haley, Kristine N. Molnar, and Michael J. Hagan.

Business Advisory Councils *(as of December 31, 2005)*

Business Advisory Council members are a diverse group of Fourth District businesspeople who advise the president and senior officers on current business conditions.

In 2005, the Bank's Business Advisory Council expanded into three councils—in Cleveland, Cincinnati, and Pittsburgh—to provide greater regional presence and outreach.

Each council meets with senior Bank leaders at least twice yearly. These meetings provide anecdotal information that is useful in the consideration of monetary policy direction and economic research activities.

Cleveland

Gerald E. Henn
Founder and President
Henn Corporation
Warren, Ohio

Christopher J. Hyland
Chief Financial Officer
Hyland Software, Inc.
Westlake, Ohio

Gary A. Lesjak
Chief Financial Officer
The Shamrock Companies Inc.
Westlake, Ohio

Rodger W. McKain
President
SOFCo-EFS Holdings LLC
Alliance, Ohio

Kevin M. McMullen
Chairman and CEO
OMNOVA Solutions Inc.
Fairlawn, Ohio

Michael J. Merle
Executive Vice President
Ray Fogg Building Methods, Inc.
Brooklyn Heights, Ohio

Frederick D. Pond
President
Ridge Tool Company, Inc.
Elyria, Ohio

Scott E. Rickert
President and Co-founder
Nanofilm, Corporate Headquarters
Valley View, Ohio

Jack H. Schron, Jr.
President and Chief Executive Officer
Jergens, Inc.
Cleveland, Ohio

Steven J. Williams
President and Chief Executive Officer
Elsons International, Inc.
Cleveland, Ohio

Cincinnati

Cynthia O. Booth
President and Chief Executive Officer
COBCO Enterprises
Cincinnati, Ohio

Charles H. Brown
Vice President of Accounting and Finance
Toyota Motor Manufacturing North America, Inc.
Erlanger, Kentucky

Ronald D. Brown
Chairman, President, and Chief Executive Officer
Milacron Inc.
Cincinnati, Ohio

James E. Bushman
President and Chief Executive Officer
Cast-Fab Technologies, Inc.
Cincinnati, Ohio

Frederick W.P. Buttrell
President
Comair, Inc.
Erlanger, Kentucky

Richard O. Coleman
President and Chief Executive Officer
GenStone Acquisition Company
Cincinnati, Ohio

Jerry A. Foster
President
Diversified Tool & Development
Richmond, Kentucky

Edward R. Jackson
President and Chief Executive Officer
Fierro Technologies, Inc.
Cincinnati, Ohio

Rebecca S. Mobley
Co-owner, Broker, and Relocation Director
TurfTown Properties, Inc.
Lexington, Kentucky

Joseph L. Rippe
Partner
Rippe & Kingston, Co. psc
Cincinnati, Ohio

Pittsburgh

R. Yvonne Campos
President
Campos, Inc.
Pittsburgh, Pennsylvania

Renee S. Frazier
Senior Vice President and Executive Officer
VHA Pennsylvania
Pittsburgh, Pennsylvania

D. Michael Hartley
Chairman and Chief Executive Officer
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State Growth Empirics: The Long-Run Determinants of State Income Growth

by Paul W. Bauer, Mark E. Schweitzer, and Scott Shane

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Real average U.S. per capita personal income growth over the last 65 years exceeded a remarkable 400 percent. Also notable over this period is that the stark income differences across states have narrowed considerably: In 1939 the highest income state's per capita personal income was 4.5 times the lowest, but by 1976 this ratio had fallen to less than 2 times. Since 1976, the standard deviation of per capita incomes at the state level has actually risen, as some higher-income states have seen their income levels rise relative to the median of the states. A better understanding of the sources of these relative growth performances should help to characterize more effective economic development strategies, if income growth differences are predictable. In this paper, we look for statistically and economically significant growth factors by estimating an augmented growth model using a panel of the 48 contiguous states from 1939 to 2004. Specifically, we control for factors that previous researchers have argued were important: tax burdens, public infrastructure, size of private financial markets, rates of business failure, industry structure, climate, and knowledge stocks. Our results, which are robust to a wide variety of perturbations to the model, are easily summarized: A state's knowledge stocks (as measured by its stock of patents and its high school and college attainment rates) are the main factors explaining a state's relative per capita personal income.

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I. Introduction

Can states use economic development policy to boost the average personal income levels of their citizens? This is certainly a major aim of most state economic development policies; yet neoclassical growth theory does not offer much hope of success for such policies. It predicts that capital mobility alone will lead to fairly quick convergence in per capita personal incomes across U.S. states. Unlike nations, U.S. states lack barriers to the flow of information, labor, and capital across boundaries that could preclude convergence (Barro and Sala-i-Martin, 1991; 1992). In fact, many researchers have noted that the tendency toward convergence over time in the per capita income of U.S. states supports the neoclassical view, at least when compared to the international results (Caselli and Coleman, 2001).

However, this convergence is not complete, and it appears to have stalled since the mid 1970s (see the top left panel of Figure 1). Many explanations have been offered for differences in economic performance at the state or metropolitan level. Some researchers have focused on differences in tax policy (Easterly and Sergion, 1993; Mofidi and Stone, 1990; Phillips and Gross, 1990), others on varying rates of investment in public infrastructure (Aschauer, 1989; Evans and Karras, 1994; Wylie, 1996). Still others have argued that past industry structure may aid or inhibit future economic development (Higgins, Levy, and Young, 2006). For others, climate differences combined with the advent of affordable air conditioning play a prominent role (Barro and Sala-i-Martin, 1991). Other explanations center on financial markets and economic performance (Abrams et al., 1999; King and Levine, 1993; Levine, 1997; Montgomery and Wascher, 1988; Rousseau and Wachtel, 1998). Last, but certainly not least, many researchers have focused on knowledge and technology. Their explanation is based on the empirical observation that higher levels of per capita personal incomes are associated with greater knowledge stocks (Glaeser and Saiz, 2004). By knowledge stocks we mean the accumulation of productive information in the form of education and technology.

Because our results overwhelmingly support the knowledge-stock explanation, it is appropriate to review this literature more thoroughly. Researchers have offered a variety of explanations for the mechanism underlying the positive statistical association between knowledge stocks and per capita personal incomes at the state level: (1) workers with more knowledge are more productive; (2) education and technology allow more people to be employed in high productivity jobs (Rangazas, 2005); (3) education and technology allow people to adapt in response to negative economic shocks; (4) education and technology make people more creative (Glaeser and Saiz, 2004); and (5) education and technology allow people to adopt new technology from other places (Benhabib and Speigel, 1994; Barro, 1997).

Education and technology constitute much of states' knowledge stocks, and one might wonder why the greater levels of education and technology of some states does not dissipate to others, leading to a equalization of knowledge stocks. While some dissipation occurs, the diffusion across state borders is likely to be incomplete. Migration of people is costly, and not all people will migrate even when entities in other states pay higher wages for their education (Barro and Sala-i-Martin, 1991). Also, knowledge spillovers appear to decrease with distance, making it harder for entities in other states to fully imitate the technology developed in a state (Griliches, 1979). Furthermore, research shows very little evidence of externalities in human capital at the state level (Rangazas, 2005). Consequently, some portion of a state's knowledge stock will remain in that state, and the larger knowledge stocks of some states will enhance their relative level of per capita personal income (Barro and Sala-i-Martin, 1991).

In order to investigate the effect of knowledge stocks and the other possible explanatory variables on per capita personal income, it is important to embed them within a growth model that allows for the convergence in per capita incomes due to the relative freedom of movement in capital and labor across state borders. So we embed a variety of state-specific labor augmenting factors into a standard neoclassical growth model. This allows the state-specific component of the standard technology term to vary in a manner consistent with endogenous growth theory (see Romer, 1986). As factors, we include measures of states' knowledge stocks, along with other factors that have been argued to explain per capital personal income levels—public finance, business environment, and meteorological climate. We find that our empirical results are driven by our three measures of a state's stock of knowledge: the proportion of the population with at least a high school degree, the proportion of the state's population with at least a bachelor's degree, and the stock of patents held by people or businesses in the state.

This paper incorporates a couple of advances on the previous literature in this area. First, we examine a longer time period than previous researchers, exploring differences in relative levels of per capita income among the 48 contiguous states from 1939 to 1999. The longer time frame gives us greater statistical precision, allowing us to tease out the effects of factors that have weaker effects on relative per capita income growth, and that might have been obscured in previous studies.

Second, we control for all classes of variables that previous researchers have argued affect relative per capita income levels across states, including a state's tax burden, its investments in public infrastructure, the size of its private financial markets, its rate of business failure, its industry structure, and its climate (Barro and Sala-i-Martin, 1991; Glaeser and Saiz, 2004; Caselli and Coleman, 2001; Kim, 1998). By including variables that account for a wide range of alternative explanations, we can estimate the magnitude of the effect that investments in knowledge will have relative to investments in the other factors that affect income growth. We can also mitigate the imprecision of these estimates of investment effects that stems from omitted variable bias.

In a study as ambitious as this one, it is important to thoroughly explore the robustness of our findings. Of particular concern is the possible endogeneity of most of the explanatory variables. For example, a problem with many efforts to associate international differences in knowledge stocks and levels of per capita personal income is the endogeneity of education outcomes (Bils and Klenow, 2000). An exogenous factor might make the level of per capita personal income in some states higher than other states. Those states might use that extra income to consume more knowledge. As a result, knowledge stocks and per capita personal income could be positively correlated without knowledge stocks directly causing one state's per capita personal income to be higher than another's. We test for predetermination of the explanatory variables using instruments based on lags of differing duration and show that a five-year lag removes (statistically) the threat of endogeneity.

Under all perturbations, we find that the knowledge variables play the main role in accounting for relative levels of per capita income across states. Their magnitude and statistical significance dominate the other explanatory variables. Moreover, within the set of knowledge factors, we find that investments in technology, as measured by the stock of patents, play the largest role in explaining the differences in per capita personal incomes across states.

The paper proceeds as follows: The next section presents our modified growth model. The third section describes the data and the variables. The fourth section presents our results. The final section concludes.

II. Model

Growth theory strives to explain how an economy's output, investment, and employment evolves in the long run. Solow (1956) provided a major advance to the field by focusing the analysis on the production function associated with current technology. Along with diminishing marginal returns to capital, introducing capital mobility implies a strong underlying tendency for income convergence through capital equalization. A shortcoming of his approach is that technological innovation, the Solow residual, enters the model exogenously. Romer (1986) pointed out that the development of innovations usually requires some diversion of productive resources away from current consumption, indicating that technological innovation is endogenous.

We take Romer's (1986) critique of growth theory to heart by including in our model measurable factors that might enter into the aggregate production function of that state. These factors do not reveal the actual process of resource diversion but can reveal value-producing differences in the underlying production function. Specifically, we embed a variety of labor-augmenting factors into a standard neoclassical growth model, allowing the state-specific component of the standard technology term to vary.

At any given time t, the income ($Y_{t,s}$) of state s is assumed to follow a Cobb-Douglas function of its capital ($K_{t,s}$) and labor ($L_{t,s}$).

$$Y_{t,s} = K_{t,s}{}^{\alpha}\left(L_{t,s}X_{t,s}^{\gamma}A_{t}\right)^{1-\alpha} \tag{1}$$

The equation also contains the familiar labor-augmenting rate of productivity growth in the national economy (A_t), which accounts for all increases in labor-augmenting productivity including the average of any state-specific labor-augmenting factors at time t. State-specific labor augmenting factors $X_{t,s}$, allow for relative differences in the state-varying factors. Without the addition of these state-specific factors, this equation is completely standard in the international income convergence literature (Islam, 1995).[1] Although Islam and others have accounted for human capital differences in a similar manner, we can do so with greater precision because we have a longer time period and we can control for more factors. The data available for U.S. states are richer than what is available internationally, allowing us to examine a wider set of factors.[2]

Specifically, we examine a set of factors that might offer a production benefit, such as human capital or public infrastructure, and that are either a characteristic of the resident workforce or that are more available to that workforce than to other workforces. By construction, the aggregate productivity level (A_t) will capture the average effect over all 48 states of all such production amenities, while the state factors are measured relative

[1] For ease of exposition in the development of our model, we treat X as a single factor. It is straightforward, but more tedious, to reformulate our exposition by modeling X as a log-linear function of multiple factors, Z.

[2] More factors could be considered with a shorter period, but we believe that the longer period is more desirable because it provides more reliable estimates of the effects. Higgins, Levy, and Young (2006) follow this former approach using many factors in a shorter panel of U.S. county-level data.

to the overall average and thus have a mean of one. This construction makes the estimation of the *X* variable a between-state estimator of the full effects in cases where the *X* variable is likely to have general as well as relative effects.

In our baseline model, we also control for one factor that is not typically thought to be labor augmenting: climate. A favorable climate could be a local amenity that boosts productivity and thus incomes. Alternatively, a climate considered favorable by residents might make them willing to accept a lower income rather than relocate.

There are other variables that we would have liked to have included in the model but that are unobserved. These missing variables could bias our results if they are correlated with the variables we include. As part of our efforts to explore the robustness of our results, we also employ a fixed effects estimator. This estimation approach controls for unobserved fixed-state effects, thus providing a powerful cross check of our findings.

U.S. states have few barriers to capital mobility, and this should speed their income convergence.[3] If we make the assumptions typical of the growth literature (see Islam, 1995), solve for the steady-state equilibrium, and allow for dynamic adjustment toward this steady-state equilibrium, we can obtain the following reduced-form equation,

$$\ln(y_{t,s}) = \beta_o + \beta_1 \ln y_{t-\tau,s} + \beta_2 \ln X_{t-\tau,s} + \beta_3 D_t + \upsilon_{t,s} \qquad (2)$$

where D_t is a set of T-1 time dummies, which capture all the national trends (in particular, inflation, technological progress, and the average effect of the *X* variable.)

[3] Income differences might be also countered by labor mobility, although relative housing costs and regional preferences might cause net flows to cease before labor mobility can offset the value of local amenities (Roback, 1982). Also, if the quality of the local workforce is the productive amenity (or dis-amenity), then mobility would not be induced either into or from an area.

The key feature of this equation is that it allows for the estimation of the state-specific effects jointly with the underlying convergence process. The existence of a labor-augmenting factor ($X_{t,s}$) introduces the possibility of persistently higher (or lower) per capita incomes. The literature on income convergence has varied on the functional form of the estimates, but most of the cross-sectional or panel results can be transformed to be similar to our estimation. Barro and Sala-i-Martin (1991) estimate the relationship non-linearly in order to focus on the adjustment parameter, but taking the log of their specification results in an algebraically equivalent form. β convergence, when the partial correlation between growth in income over time and its initial level is negative, is implied in our estimates when β_1 is less than 1. Islam (1995) raises the possibility of conditional convergence which adds a set of state-specific dummy variables to equation 2. We will consider this approach as an alternative to our baseline.

A critical issue to consider is the potential for X endogenously responding with the income level. If the *X* variable is exogenous, there is no need to use a lagged value as an instrument; just set $\tau = 0$. However, international growth studies clearly find problems with treating the likely *X* variables as exogenous (see, for example, Bils and Klenow, 2000). Current values of the *X* variables are likely to be a function of any difference in the states' past levels of the same *X*, realized current income, and some expectation of relative future income prospects of the region (represented below as a linear function of future income surprises).

$$E(\ln X_{t,s}) = a_{t-\tau} + \phi \ln X_{t-\tau,s} + \varphi \ln y_{t-\tau,s} + E(\ln e_{t,s}) + E\left(\sum_{i=0 \text{ to } \tau} \eta_i \upsilon_{t-i,s}\right) \quad (3)$$

At some lag τ, however, it is likely that future errors (or innovations), $\upsilon_{t,s}$ are uncertain enough that they no longer alter the realizations of the *X* variables τ years. If *X* is predetermined in this sense at a τ-year lag, then the future value of the *X* variables is simplified:

$$E(\ln X_{t,s}) = a_{t-\tau} + \phi \ln X_{t-\tau,s} + \varphi \ln y_{t-\tau,s} \qquad (3')$$

The second equality follows because for $E(X_{t,s})$ to be zero by construction, the expected innovation ($v_{t,s}$) will be zero for an appropriate *a*. We do not assume predetermination of the *X* variables; instead, we test whether this condition holds. Predetermined *X* variables allows for consistent and efficient estimation of (2) using OLS.

While we can learn several key aspects of the relevance of state-level regressors on income levels from the regression shown in equation (2), accounting for the correlation with the other variables in the model is necessary to estimate the effects of these explanatory variables on income convergence across states. In Barro and Sala-i-Martin (1991) terms, this evaluates the role of the variables in state-level σ convergence, when the dispersion of real per capita income across a group of economies falls over time. Taking the standard deviation of both sides of equation (2) and focusing on the *X* variables results in the following relationship,

$$\begin{aligned} \operatorname{var}(\ln \hat{y}_{t,s}) &= \operatorname{var}(\hat{\beta}_o + \hat{\beta}_1 \ln y_{t-\tau,s} + \hat{\beta}_3 D_t) + \operatorname{var}(\hat{\beta}_2 \ln X_{t-\tau,s}) \\ &\quad + 2\operatorname{cov}\left(\hat{\beta}_o + \hat{\beta}_1 \ln y_{t-\tau,s} + \hat{\beta}_3 D_t, \hat{\beta}_2 \ln X_{t-\tau,s}\right). \end{aligned} \qquad (4)$$

We have every reason to suspect that the covariance in equation (4) will not be zero and may be quite important in the determination of income variation across states.

We will present many of our results in terms of the variance with and without particular components of *X*. For example, to estimate how much of the variation can be explained we exclude all of the *X* variables by setting their values to zero:

$$
\begin{aligned}
\operatorname{var}(\ln\hat{y}_{t,s}) - \operatorname{var}(\ln\hat{y}_{t,s} \mid \ln X_{t-\tau,s} = 0) &= \operatorname{var}(\hat{\beta}_o + \hat{\beta}_1 \ln y_{t-\tau,s} + \hat{\beta}_3 D_t) + \operatorname{var}(\hat{\beta}_2 \ln X_{t-\tau,s}) \\
&\quad + 2\operatorname{cov}\left(\hat{\beta}_o + \hat{\beta}_1 \ln y_{t-\tau,s} + \hat{\beta}_3 D_t, \hat{\beta}_2 \ln X_{t-\tau,s}\right) \\
&\quad - \operatorname{var}(\hat{\beta}_o + \hat{\beta}_1 \ln y_{t-\tau,s} + \hat{\beta}_3 D_t) \\
&= \operatorname{var}(\hat{\beta}_2 \ln X_{t-\tau,s}) \\
&\quad + 2\operatorname{cov}\left(\hat{\beta}_o + \hat{\beta}_1 \ln y_{t-\tau,s} + \hat{\beta}_3 D_t, \hat{\beta}_2 \ln X_{t-\tau,s}\right)
\end{aligned} \tag{5}
$$

This approach summarizes both the direct effect of the *X* variables on expected income variation and the effects of covariation between *X* and income levels. In the results section, we report a variety of estimates of the standard deviations (the square root of the variance), which are calculated by zeroing out selected regressors, in order to illustrate their estimated effect on per capita personal income convergence.

III. Data

In this section we describe the data we collected to estimate our growth model, focusing on the motivation, source, and construction of the regressors we employ. One of our goals is to extend the sample back as far as possible so that we can study the long-run evolution of state per capita personal incomes. We also include explanatory variables that previous researchers have argued are important. The larger sample should increase the statistical precision of our results, enabling us to tease out even weak effects. Moreover, by including variables that account for all the proposed explanations, we should be able to sort out how much each factor drives state per capita personal income, and mitigate bias from omitted variables.

Collecting a data set like this is very challenging. Some of our variables go farther back than others, and the historical series for the variables vary by state. The banking data turned out to be the limiting factor in our data set, as deposit information by state only goes back to 1934. As our baseline model has five-year lags, this means our first observations are from 1939. Our last observations are from 2004, which means we have per capita personal income from that year, but for the lagged explanatory variables values are from 1999. Data availability also led us to consider only 48 contiguous states because data for Alaska, Hawaii, and the District of Columbia are incomplete. Because we omit the years in between the five-year periods in order to avoid artificially underestimating the standard errors,[4] we are left with a panel of 48 states over 14 five-year periods. Although this approach may seem drastic because it tosses away observations that could be retained if the time series properties of the errors were modeled explicitly, the approach has the advantage of being more flexible. In addition, because our educational attainment data are only available decennially from 1940 to 1980, (details to come), we are not really discarding as much information as it appears. Thus, our approach is appropriately conservative.

Our measure of a state's economic performance is per capita personal income, and the dependent variable is constructed by taking the natural log of the ratio of the Bureau of Economic Analysis's personal income series and the Census Bureau's population estimate for a given state at time *t*.

[4] We drop these observations to avoid having to model the time series properties of the residual.

We will now describe the set of regressors we employ to estimate the model. The first two types are mainly control variables—they are not the focus of our study, but they need to be included in order to obtain consistent estimates of the coefficients of the factors in which we are interested. First, we include a lagged dependent variable because equation (2) calls for it in order to capture the dynamic adjustment process. Second, we include year-time dummies, which capture the national movements in prices and also the average effects across states of movements in technology. They also pick up any other national trends that might be in the data.

We include a variety of explanatory variables that might alter convergence rates across states. All of these regressors are transformed as the natural log of the state's value at a given time, divided by the population-weighted average for all of the states in the sample. Thus, the average effect for a particular untransformed variable is captured by the year dummies, while the regressor captures that variable's relative effect.

As discussed earlier, we include several classes of variables that might influence a state's rate of convergence. A key class of variables we call knowledge variables. These variables seek to measure a state's stock of knowledge. Two of these variables measure educational attainment. The first is the proportion of a state's population with at least a high school degree The other is the proportion with at least a bachelor's degree. For 1979-2004 our source for these data is the annual Current Population Survey. For prior years, decennial data are available from the Census Bureau, which we interpolate as required for intermediate years. Because educational attainment moves only slowly over time, the interpolated values (and the extrapolated values for 1934) are reasonable (see Figure 2).

Our other knowledge variable is a state's stock of patents. This variable proxies for a state's ability to innovate new products and production techniques that could give it an economic edge and lead to higher relative per capita personal incomes. A state with a larger stock of patents is presumed to be more innovative in creating new products and production techniques. Patent data by state are available in the *Annual Report of the Commissioner of Patents and USPTO* for the years 1917 to 2001. To calculate our stock variable we employ a perpetual-inventory approach. To estimate the initial stock for a given state, we take the average number of patents issued from 1917 to 1919 and divide by an assumed depreciation rate. For subsequent years, a given year's stock is equal to the previous year's stock times the depreciation rate plus the number of patents issued in that year.

Our baseline model assumes a 5 percent depreciation rate. Faster assumed depreciation rates make the initial stock estimates less important. With a 5 percent depreciation rate, only 46 percent of the initial stocks are left in each state's patent stock in 1934, the first lag used. The assumed depreciation rate does not appear to be critical because we obtain very similar results for a wide range of depreciation rates (1 percent to 100 percent).

Public finance—the way in which states raise and spend tax revenue—is widely thought to influence a state's economic performance, and it comprises another set of explanatory variables. Many analysts focus on tax rates (Mofidi and Stone, 1990; Phillips and Gross, 1995). Therefore, we include a measure of tax rates. Our tax rate variable is a state's total tax revenue (from Financial Statistics of States) net of severance taxes (in the early years from the Census Bureau and in later years from the Department of Energy) over the state's personal income. We need to emphasize that this variable is not the tax rate on labor. It is a measure of a state's overall tax burden, but it does not control for how those taxes are actually levied, which could be important.

Other researchers have argued that expenditures on public infrastructure are an important growth factor (Aschauer, 1990; Wylie, 1996). Thus, we include a measure of infrastructure expenditures. Our proxy for public capital, highway capital, is constructed using a perpetual-inventory approach. Our measure of highway spending comes from the Financial Statistics of States. The data become available for states in various years from 1917 to 1925. The initial stock for a state is calculated as the average of that state's first three years of observations divided by the assumed rate of depreciation. In our baseline model, we set depreciation equal to 5 percent, but, as with patent stocks, our results are robust over a wide range of values.

Our last set of explanatory variables describes a state's business environment. Some researchers think that the extent of private financial markets within the states influences their economic performance (Abrams et al, 1999). Our measure of private financial markets within the states is based on the amount of dollars in bank deposits, which is available from the FDIC's Summary of Deposit series after 1966. For prior years, we spliced in Call Report data for domestic deposits. An alternative interpretation of this variable is that it is a proxy for a state's private capital stock.

Some analysts think that economic dynamism influences economic performance (Montgomery and Washer, 1988). We capture dynamism with a measure of business failure rates. Our failure-rate variable is the number of bankruptcies in a year divided by the total number of business concerns in the state. The ultimate source for these data is the Statistical Abstract of the United States and the Metropolitan Area Databook.[5]

Over time, the desirability of different industries may have changed, yet states can not adjust their industry make-up instantaneously, or without cost. The industry structure factors control for a state's previous economic makeup, specifically the composition of its sector specific capital and worker's human capital. Industry structure is measured as the shares of a state's personal income derived from manufacturing, farming, and mining, respectively. Implicitly, a state low in all of these industry structure variables will have a relatively large serviced sector.

We also control for a state's meteorological climate as measured by heating-degree days, cooling-degree days, and inches of precipitation. These data are available from the National Oceanic and Atmospheric Administration. Because they are annual averages from 1929 to 2003, they are constant over time.

Some insight can be gained by looking at the raw variables. Table 1 presents the values of per capita personal income and the various explanatory variables for the first and last observations for each state (1939 and 2004 data for personal income and 1934 and 1999 data, because of the lag, for the explanatory variables). Population grew in every state except North Dakota over this period, and every state experienced rapid growth in its per capita personal incomes. Among our knowledge-stock variables, both high school and college attainment have increased dramatically, while patents per capita have remained relatively flat. Some researchers have noted that the value of patents may have changed over time (see Griliches, 1990). Any inflation or deflation of the quality of

[5]This variable required a fair amount of splicing and interpolation (contact authors for more details).

patents over time will be filtered out because the patent variable in the model is relative to the average of these states.

Among the other classes of explanatory variables, tax rates (tax revenue over personal income) rose over this period, but not as dramatically as highway capital. By contrast, failure rates rose slightly, but as we will see in a moment, this masks a great deal of volatility over time. Bank deposits actually fell substantially over this period because of disintermediation. Savers have many more options today over where to put their funds, such as money market accounts and mutual funds. One thing is very clear from Table 1: there is a wide range of variation in most of these variables across states even though they tend to follow the same general trends.

Further insights can be gleaned by plotting the raw data. Figure 1(a) plots the course of the standard deviation of our dependent variable (the natural log of real per capita personal income) from 1934 to 2004. These standard deviations are a measure of how much per capita personal incomes vary across states in each year. After a slight downward trend in the late 1930s, there was a rapid surge towards convergence during World War II (WWII). Following the end of the war, convergence slowed but continued to decline at a steady pace through the late 1970s. Since 1970, convergence has basically leveled off.

Figures 1(b-d) are similar plots for the explanatory variables. The convergence in high school attainment (high school+) has been remarkable, falling about 80 percent. In contrast, there has been almost no convergence in college attainment (college+). It is worth knowing how the levels of these variables have moved overall. Figure 2(a) plots the rise in high school and college attainment over time. Only about 20 percent of the population had at least a high school degree in 1934, but by the end of our sample, well over 80 percent had achieved this level of education. Gains in this variable have sharply leveled off in recent years. As for college education, in 1934 less than 4 percent of the population had at least a bachelor's degree, but, by 1999, this figure had risen to 25 percent. Unlike high school attainment, gains in college attainment, which accelerated around 1970, show no sign of easing. Currently, while there are no outliers for high school attainment (defined as more than two standard deviations from the mean), Arkansas and West Virginia are both negative outliers for college attainment.

For patents, our other knowledge variable, the spread across states narrowed about 25 percent over this period. Delaware is the only positive outlier for the patents variable, and no state is a negative outlier. In Figure 2(b), we see that per capita patents fell sharply during WWII but recovered in the late 1940s and held at the 1940s level through the mid-1970s. Since 1980, patents per capita have risen sharply and have accelerated since 1997.

Our business-failure rate is fairly volatile over time. However, it shows no more tendency toward convergence than do our variables for tax rate, highway capital, or bank deposits. Interestingly, the variable with the smallest standard deviations over time is the tax rate variable, which has been fairly stable over the last 30 years.

There has been more movement in the industry-structure measures. Manufacturing's standard deviation has fallen by a about a third over this period. Although historically there have been many large outliers for manufacturing, at present, no state deviates from the mean by more than 2 standard deviations. Mining's standard deviation, on the other hand, has only narrowed by about an eighth. West Virginia had been a big positive outlier in mining through the mid-1970s, but is no longer one. Only Wyoming is currently more than 2 standard deviations above the mean. In sharp contrast to the other two measures of industry structure, farming's standard deviation has actually diverged by about a fifth. The positive outliers with this variable are Nebraska, North Dakota, and South Dakota. Large negative outliers are Massachusetts, Rhode Island, and West Virginia.

IV. Results

In this section we discuss our baseline estimates. We then explore how robust our estimates are to alternative assumptions. Finally, we take a closer look at the results by looking at state-specific estimates.

Endogeneity and Lags

The baseline model assumes that the parameters are fixed over time and that a 5-year lag is sufficient to handle any endogeneity of the explanatory variables. Contemporaneous observations of the explanatory variables are likely to be endogenous, so employing them would lead to biased and inconsistent estimates. Using instrumental variables can provide consistent estimates of the model's parameters, and lagged values make good instruments. We use the same lag length for the lag of the dependent variable, even though the motivation for this lag stems from the partial adjustment process.

The key to the instrumental-variable approach is to find instruments that are highly correlated with the regressors, yet are uncorrelated with the error term. Lagged values of the regressors are likely to meet both of these criteria, but how long should the lag be? A longer lag makes it more likely that the possible endogeneity is removed but lowers the correlation between the lag and the instrumented variable. Also, assuming a longer lag effectively reduces the number of observations available for analysis.

Intuition suggests a 5-year lag is a reasonable value to balance these trade-offs. Of course, this assumption needs to be tested, and we do this using the Durbin-Wu-Hausman (D-W-H) test (see Baum, Schaffer, and Stillman, 2003), which can be used to test whether a regressor, or subset of regressors, is endogenous. The test compares an estimator that is consistent, whether or not the subset of variables is predetermined, with an estimator that is consistent and more statistically efficient only if the set of variables is predetermined.

Table 2 reports D-W-H test results for various lag lengths for the regressors taken as a group and then for each one individually. For our always-consistent estimator, we employ 10-year lags as instruments. The estimator that is consistent only if the subset of variables is predetermined employs the specified lag. Note that as the lag length varies, the data employed to calculate the tests change for two reasons. First, changing the lag length necessarily shifts the associations among the variables. The second reason is more subtle: increasing the lag length trims the number of observations, whereas trimming the lag length increases the number of observations.

With lag lengths less than 5 years, the null hypotheses that the variables are predetermined are soundly rejected at the 5 percent confidence level. For 5-year lags, the null is accepted for the joint test and for each explanatory variable individually—although this is a very close call with the tax-rate variable. While a 6-year lag is even less significant under the joint test, the individual tests for patents and tax rates are both rejected. Thus, when seeking a balance between handling endogeneity with sample size, we find that a 5-year lag is the best choice.

Baseline Results

Our baseline estimates, calculated from a panel OLS estimator, are reported in Table 3, column 1. Conventional measures of model fit are high enough to be irrelevant ($R^2 = 0.9983$), primarily due to the importance of the time dummies and the lagged dependent variables in fitting the level of incomes. A model with only these variables generates an R^2 of 0.9976. A more informative measure of the goodness of fit is how much of 2004's *relative* personal per capita incomes are explained by our posited growth factors. The correlation between the actual and fitted values is fairly high (0.78), suggesting that the model explains about 78 percent of this variation.

From the perspective of state income differences, a more informative comparison can be made between the standard deviation of the estimates implied by the model and the actual income differences across states over time. Figure 3 shows the standard deviation of the predicted and actual log per capita income levels. Although the high R^2 does not convert into perfect predictions of the path of income convergence, the fit is quite good, except for the initial sharp decline in income differences, which is underpredicted in the model.

Some understanding of the determinants of income growth can be gained by looking at the estimated parameters. The estimated coefficient on lagged logged per capita income is less than one (0.67). Because state per capita personal income is measured relative to the national trend, a value less than one implies convergence. Other things equal, this rate of convergence would halve the standard deviation of per capita incomes in just 10 years. In 30 years, it would be less than a tenth of its starting value. In the model with no other explanatory variables than the time dummies, the coefficient on lagged per capita personal income is estimated to be 0.85, more than doubling the estimated number of years needed to achieve similar levels of convergence.

Implicitly, the difference in the coefficient on lagged per capita personal income between the two models (one with all the explanatory variables and the other with only the lagged dependent variable and the time dummies) reveals that state-level differences in the *X* variables have significantly reduced the amount of income convergence that has been realized, even though most of these variables have experienced some convergence across states as well. In other words, convergence would be faster if all states realized the same values for the explanatory variables. We now consider each of these factors in turn.

Knowledge Variables

All of the coefficients of the knowledge variables (high school+, college+, and patent stocks) have the expected sign and are statistically significant. Each plays a role in enabling some states to achieve and maintain higher per capita personal income relative to other states. Other things being equal, being one standard deviation above the states' average in the percentage of the population that has graduated from high school (a 20 percentage point increase) leads to 1.5 percent higher per capita personal income. Thus, the sharp rise of high school attainment in the sample is estimated to account for a sizeable portion of the income gains. However, further progress from this source is likely to be small. In 1999 (the lag used for 2004), high school attainment for these states averaged 83.3 percent. Even so, there remains a fairly wide range of achievement rates. West Virginia has the lowest rate of high school attainment at 75.1 percent, while Washington's stands at 91.2 percent.

Similarly, we find a positive and statistically significant effect for the log of the deviation from the states' average in the percent of the population that are college graduates. Other things being equal, a one–standard-deviation increase above the states' average in the percentage of the population that has graduated from college (23 percentage points higher) leads to 1.4 percent higher per capita personal income. There is more room for improvement in college attainment than high school attainment: The states' average of this rate stood at 25.2 percent in 1999, and the rates of individual states vary from a low of 17.3 percent (Arkansas) to a high of 38.7 percent (Colorado).

Our patent-stock variable measures a different dimension of knowledge, a state's ability to innovate new products and production techniques. Other things being equal, a one-standard-deviation increase above the states' average in the stock of patents per capita (75 percentage points higher) leads to 3.0 percent higher per capita personal income. This is a large effect, and it is also relatively tightly estimated with a t-statistic of over 6. While the spread of the patent variable has narrowed by about half over time, from a factor of about 30 in 1934 to about 15 in 1999, the range is still very wide.

Figure 4 compares the implied effects of the knowledge variables on the standard deviations in the baseline model. Each line is the standard deviation of the predicted effect for the indicated variable. For comparative purposes, the figure also includes the standard deviation of predictions when all of the *X* variables are used in the model (but not the lagged dependent variable or time dummies). These estimates can either offset or amplify one another. Clearly, some of the effects are offsetting as the standard deviation of all variables is not much higher than just the patent effect alone. Finally, note that because of the decline in the variation across states of high school attainment the role of this factor declines noticeably over time, while differences in college attainment are more persistent, and end up being more important than the high school effect.

Industry Structure

Of the industry-structure variables, only manufacturing and farming's are ever statistically significant (see Table 3, column 1). The share of personal income derived from manufacturing has the clearest effect on relative per capita income—lowering expected current income levels relative to past income levels. Although income levels are relatively high in states that specialize in manufacturing at the start of the sample, these states either shift out of manufacturing or experience relatively weak income gains. Indeed, having a one-standard-deviation-higher share of manufacturing income (a 58 percent higher share than the states' average) lowers expected income growth by 2 percent, which is, again, an important difference.

Mining is also a statistically significant and negative factor, although its coefficient is far smaller. A one-standard-deviation increase in the mining share (a 142 percent larger share of income derived from mining than the states' average) lowers average income 1.1 percent. Farming is an insignificant factor, which might be surprising, given the steady decline in employment seen in this sector.

Figure 5 reveals that for explaining income differences, only the manufacturing effect has anywhere near the magnitude of the knowledge variables, and then it is only about the size of the educational attainment variables. Over time, as manufacturing levels have converged across states, the manufacturing effect explains less of the variation in income levels. The effect of mining on income differences is much smaller and is relatively unchanged over time. Farming has essentially no effect.

Climate

By design, the climate variables are constant over time. We find a statistically significant relationship for the cooling days and precipitation variables. States with a one-standard-deviation increase in log cooling days relative to the nation (about a 75 percent increase) have 1 percent higher income. Similarly, those with a one–standard-deviation-lower rate of precipitation (about a 50 percent reduction) have about 1 percent higher income.

Other Variables

The public finance variables do not have much explanatory power. The coefficient on highway capital, our proxy for public capital, is small and not statistically significant. Even if the coefficient were doubled, the effect of a one-standard-deviation increase in relative infrastructure spending would still be less than one-half of a percentage point. The story is similar for our tax variable. Its coefficient is also small and statistically insignificant. Again, its effect would remain small even if its coefficient were doubled.

Our business-environment variables also add little explanatory power. The coefficient on the failure rate of businesses, our measure of Schumpeterian creative destruction, is positive as anticipated, but not statistically significant. It also accounts for only a very small amount of the standard deviation in the dependent variable. Finally, the story for the bank-deposits variable, our proxy for private capital and the size of a state's financial markets, is again similar. Its coefficient is small and statistically insignificant, as is its estimated standard deviation. This is broadly consistent with the literature, which reports little effect of state banking activity on states' per capita income growth (see McPherson and Waller, 2000).

Explanatory Variables and Interstate Income Differences

Each of our explanatory variables could either increase or decrease income differences across states, depending on the correlation between the effect of the variable and income levels in the states. In order to assess the effects of the statistically significant variables, we perform a series of counterfactual experiments, each of which involves setting a different set of explanatory variables to zero. Rerunning the regression then allows us to calculate the fraction of the variation in state incomes which the set of variables set to zero explains.

In Figure 6 we plot the resulting shares of variation explained by the major effects. The patents variable consistently explains the largest share of the standard deviations in our dependent variable. The next-largest share is the combined effect of the educational attainment variables (high school+ and college+). The gradual decline in the importance of the education variables is a result of the declining differences in high school attainment across states discussed earlier.

The other explanatory variables account for relatively small shares of the explained variation across states. The magnitudes of the effects of the industry-structure variables are smaller, but they have increased over time. Of these variables, the manufacturing variable has the largest role. As its coefficient is negative, a greater share of manufacturing can be interpreted as exerting a drag on state per capita personal income. Given the high incomes in manufacturing states in the 1940s, the effect of this factor has been to reduce income levels below what would have been. However, since the early 1970s manufacturing intensity has been essentially uncorrelated with income.

Of the climate variables, both the cooling and precipitation variables are statistically significant. Both have a positive effect on per capita personal income. Even so, the magnitudes of the estimated effects of these variables are small.

Estimating the Model under Alternative Assumptions

In this section, we describe how our results vary as we estimate the model under different distributional assumptions, allow the model's parameters to differ over time, change the lag lengths used in the estimation, and alter the depreciation rates used in constructing the stock variables. Under all these perturbations, our central finding remains the same: The knowledge variables, particularly patents, are the key to understanding how some states persistently outperform others in terms of per capita income.

Controlling for Possible Fixed Effects

While we have made every effort to include all the relevant explanatory variables, there are certainly some we would have liked to have included but could not because the data were not available. If these omitted variables matter and are also correlated with our included variables, then our baseline results would be inconsistent estimates of the coefficients. To explore the potential for the adverse effects of omitted variables, we use a fixed effects panel estimator, which can consistently estimate the time-varying regressors even when there are omitted time-invariant regressors.

The fixed-effect-parameter estimates are reported in the second column of Table 3. Note that the climate variables, being constant over time, are stripped out of the model, as are any unobserved time-constant variables that this technique is designed to handle. The estimates do differ some from the baseline estimates, and the state fixed effects coefficients are jointly statistically significant at the 1 percent confidence level even though none of the individual state dummy coefficients is (even at the 5 percent confidence level). In fact, the magnitudes of the estimated coefficients of the knowledge variables all increase and remain statistically significant.[6] For the other explanatory variables, the results change very little, with only manufacturing's share of personal income losing its statistical significance.

The climate variables appear to have more explanatory power than the state dummies. If the dummy variables for four states are excluded from the model, the climate variables can be reintroduced to the model. By selecting four states with similar

[6] If dummies for the four Census regions (Northeast, Midwest, South, and West) are included instead of the state fixed effects, their coefficients turn out to be statistically insignificant from zero. These coefficients become statistically significant if the climate variables are also omitted from the regression. Again,, the estimated effects are essentially unchanged.

climate variables and small estimated state dummies (Mississippi, Alabama, Louisiana, and South Carolina), the remaining state dummies are centered about zero. An F-test for the statistical significance of the remaining state dummies cannot be rejected at the 95 percent confidence level. In any case, if you believe the fixed effects estimator should be the preferred one, our core findings remain unchanged.

Figure 7 illustrates the share of the standard deviation of per capita personal income explained by the fixed effects results. The time paths of the various effects are largely unchanged. The main observable shift from Figure 6 (aside from the flat-lined climate effect) is that the effect of patents is a bit lower over time. The effect of industry structure is also more muted. In short, allowing for fixed effects does not materially alter our story, suggesting that our results are not an artifact of omitted variable bias.

Allowing the Coefficients to Vary over Time

Our next perturbation of the model is to allow the coefficients of the explanatory variables to vary over time. Over a period this long, it could be argued that the underlying parameters have changed over time, either due to changes in technology or changes in political institutions. In order to determine if our results are sensitive to these underlying parameter changes, we estimate a version of the model that allows the parameters to vary over three periods within our sample, 1939 to1959, 1964 to 1979, and 1984 to 2004. With our 5-year lag, the first and last periods each have 5 cross sections while the second has only four. In this version of the model, to hold the dynamic structure of the model constant, we do not allow the coefficient of the lagged dependent variable to vary over time.

The parameter estimates of this model are presented in Table 3, columns 3 to 5. This permutation yields some larger changes. The patent effect, if anything, becomes more important, at least in the early years of the sample. While the coefficient of the patents variable is statistically significant in all three periods, its magnitude in the earliest period, 0.0749, is twice as large as it is in the two latter periods, 0.0415 and 0.0376, and is only slightly lower than the baseline model's 0.0404. An F-test for whether these coefficients are all equal cannot be rejected at the 95 percent confidence level (p-value 0.0556).

Allowing the coefficients to vary over time shifted the education variables even more. The college+ variable (0.0577 in the baseline model) ranged from 0.0275 in the middle period to 0.0753 in the last period—the only period in which the variable was statistically significant. Not surprisingly given the relatively large standard errors, an F-test cannot reject the null hypothesis that the coefficients are the same in all three periods.

The high school+ variable (0.0781 in the baseline model) also dipped from 0.0671 in the first period to 0.0241 in the middle period but rebounded to 0.0739 in the last period. Note that it was not statistically significant in any of the periods, and again the null hypothesis that the three coefficients are the same cannot be rejected. The magnitudes of these coefficients are similar to those in the baseline model, but their statistical precision is adversely affected by having fewer time series observations to estimate them with.

The tax-rate variable, the business-failure-rate variable, and the banking-deposits variable, like their baseline counterparts, are all statistically insignificant. In contrast, our highway-capital variable is statistically significant in the first period, but not in the latter two. Even so, the magnitude for this variable remains fairly small even in the period in which it is significant.

Among the industry-structure variables, manufacturing's share of personal income remains a negative influence in all three time periods, but is statistically significant in only the first and last periods. The magnitude ranges from -0.0228 to -0.0339, roughly the same as the baseline model's magnitude of -0.034. Mining's share also is estimated to exert a negative influence, the same as in the baseline model. Finally, the coefficient on farming's share remained essentially zero.

The parameter estimates of the climate variables appear to suffer from the same lack of statistical precision that the education variables do. The magnitude of the parameters is essentially the same, but the coefficient estimates are not statistically significant.

The effects of the time-varying-parameter estimates are plotted in Figure 8. The main observable shift from Figure 6 is that the effect of patents is now estimated to decline over time. The major part of this decline is due to the fact that patents explain a much larger share of the standard deviation at the beginning of the sample. Another change is that the share of the standard deviation explained by education is a bit flatter over time in the time-varying parameter model than in the baseline model. A big change from the baseline results (Figure 6) is that the effect of industry structure is now slightly larger in magnitude than the education variables. Finally, the climate variables explain a relatively small share of the standard deviation, as in the baseline results. In short, this robustness test reveals that the factors driving a state's per capita personal income remain largely unchanged, although the statistical precision suffers.

Varying the Lag Length

Another way to test the robustness of our findings is to vary the lag length. Qualitatively, our results remain the same whether the lag length is shortened to one or stretched to 20. The sixth column of Table 3 reports the parameter estimates when the lag length is set to 10 (other results can be obtained from the authors). The main change is that the coefficients for the knowledge variables are both larger in magnitude and statistical significance than in the baseline model. Once again, although there is some shift in the magnitude and trends, patents and educational attainment are still the main drivers of state per capita personal incomes (see Figure 9).

Varying Rates of Depreciation

A final set of robustness tests varied the rate of depreciation used in constructing the patents and highway capital stock measures. The results are even more robust across this dimension. Even increasing the depreciation rate to 100 percent, effectively turning these stock variables into flows, yielded largely the same parameter estimates (see last column of table 3), and the same knowledge variables explain the bulk of the variation in per capita personal incomes across states (see Figure 10). The time paths are more volatile in this figure because the patents and highway variables are not inherently smoothed as they are when they are treated as stocks, but they tell essentially the same story.

V. A Closer Look at States

More insight into how per capita personal income evolves can be gained by looking at individual states. A couple basic facts are illustrated in Figures 11 and 12, which plot the observed relative per capita incomes across states for 1939 and 2004, respectively. First, these plots show in more detail than Figure 1 how much state per capita personal incomes have converged. Much of the convergence comes from states at the lower end of the distribution moving up toward the average. In 1939, states ranged from less than -0.8 log point to more than 0.6 log point away from the overall average. In sharp contrast, the range for 2004 was only from a little less than -0.2 to under 0.4. Also, while some states have improved their relative position and some have lost ground, there appears to be a great deal of persistence in relative per capita personal incomes. This persistence makes it much less likely that the remaining wide range of outcomes is due primarily to random shocks. In other words, there is a role for factors other than convergence to explain this variation.

Figures 13 and 14 plot the predicted effects of our explanatory variables for 1939 and 2004, respectively. In both periods, high-performing states have large patent stock and educational attainment effects, while for low-performing ones these effects are large and negative. Industry structure and all the other explanatory effects play relatively minor roles. In particular, education plays a much larger role in 1939, when high school attainment varied much more across states. For example, Mississippi trailed all other states in both periods in per capita personal income, but while it has not managed to reduce the drag from its relatively low stock of patents, by 2004 it had substantially narrowed the gap in educational attainment between it and the average state. Connecticut, on the other hand, is a high-income state in both periods. In 1939, its higher levels of personal income were driven by a relatively high stock of patents, but in 2004 its relatively high level of educational attainment also played a significant role.

While effects predicted for a given period are of interest, they do not reflect the full impact of the explanatory variables over time, because previous values exert an indirect effect through the lagged value of per capita personal income. For example, a high level of the educational attainment regressor in one period not only leads to a higher level of per capita personal income in that period, but some of it is propagated into future periods through the lagged coefficient. An explanatory variable's total effect on per capita personal incomes at the end of the period can be estimated as,

$$total\_effect = \sum_{t=1}^{T} \left(\hat{\beta}_x x_t\right) \hat{\beta}_1^{\,T-t} \tag{6}$$

Note that because the lagged coefficient on per capita income ($\hat{\beta}_1$) is less than one (see Table 3), a given x_t has a diminishing effect on future per capita personal incomes the further into the future one goes.

The estimated cumulative effects for our baseline and fixed effects estimators are plotted in Figures 15 and 16. There are differences in the estimates for individual states, but the overall cumulative effects are very similar for the two techniques. The estimated effects are particularly close for the patent-stock and educational-attainment effects. Most of the differences come from industry-structure and other effects. This is not too surprising because although the coefficients on manufacturing and mining are statistically significant in the baseline model, none of the industry-structure coefficients are statistically significant in the fixed effects model (see Table 3). Consequently, their estimated effects are likely to contain a lot of noise. Also, because the effects of the climate variables are included in the "other" category in the baseline results but not in the fixed effects results (time-invariant climate variables are removed by the fixed effects estimator) the baseline and fixed effects estimates of the other effects are likely to differ.

Looking at only Figures 13 and 14, one might get the impression that while states may be able to influence their relative position, their ability is somewhat limited. After all, the best and worst states only affect their relative per capita personal incomes by less than 10 percent. However, one gets a very different impression by looking at the estimated cumulative effects. In 2004, the estimated cumulative effects account for about half of the differences across states on average in relative per capita personal incomes.

VI. Conclusion

Neoclassical growth theory suggests that the per capita personal income of residents of the U.S. states should converge over time given the absence of barriers to the flow of information, labor, and capital across state boundaries. However, as Figure 1(a) illustrates, convergence of per capita personal income levels across U.S. states is not complete and appears to have stalled since the mid 1970s. After constructing a Romer-type endogenous growth model by taking a standard Solow growth model and introducing state-specific labor-augmenting factors in order to control for the underlying convergence process, we find that a state's productive stock of knowledge appears to enhance its relative level of per capita income.

To examine the differences in relative levels of per capita income among the 48 contiguous states from 1939 to 2004, we control for classes of variables that previous researchers have argued influence relative per capita income levels across states: tax burdens, public infrastructure, size of private financial markets, rates of business failure, industry structure, and climate. We find that our three measures of a state's knowledge stock (the proportion of the population with at least a high school degree, the proportion of the state's population with at least a bachelor's degree, and the stock of patents held by people or businesses in the state) matter most. We find that these effects are robust to a wide variety of perturbations to the model. Other things equal, being one standard deviation above the states' average in the stock of patents per capita (75 percent higher) leads to 3.0 percent higher per capita personal income. Similarly, being one standard deviation above the states' average in high school attainment (a 20 percentage point increase) leads to 1.5 percent higher per capita personal income. Finally, being one standard deviation above the states' average in college attainment (23 percentage points higher) leads to 1.4 percent higher per capita personal income.

Our results are easily summarized: A state's stock of knowledge is the main factor explaining its relative level of per capita personal income. If state policymakers want to improve their state's economic performance, then they should concentrate on effective ways of boosting their stock of knowledge. Of course, further research will be needed to determine the most efficient way of accomplishing this.

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Figure 1: Standard Deviations of Variables

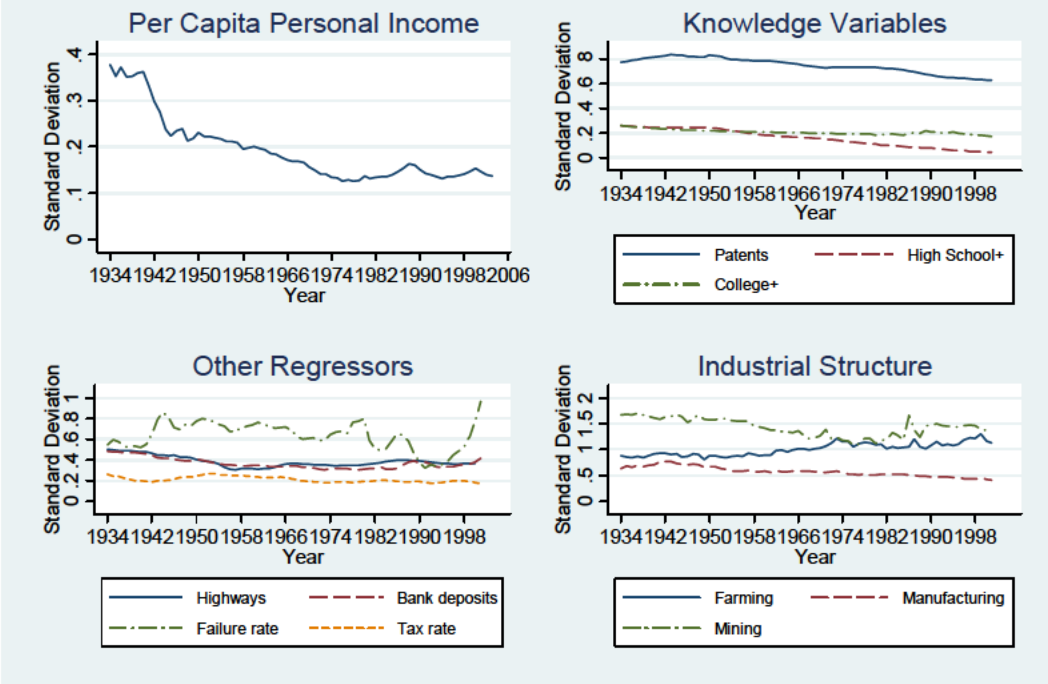


Figure 2

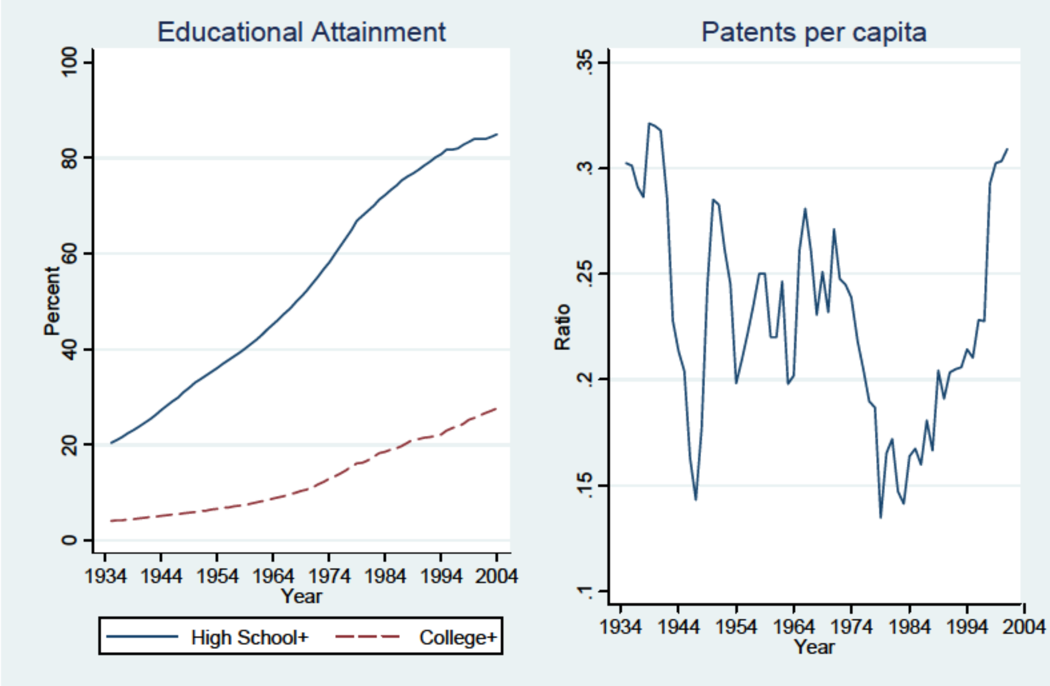


Figure 3: Model Implications for Income Convergence

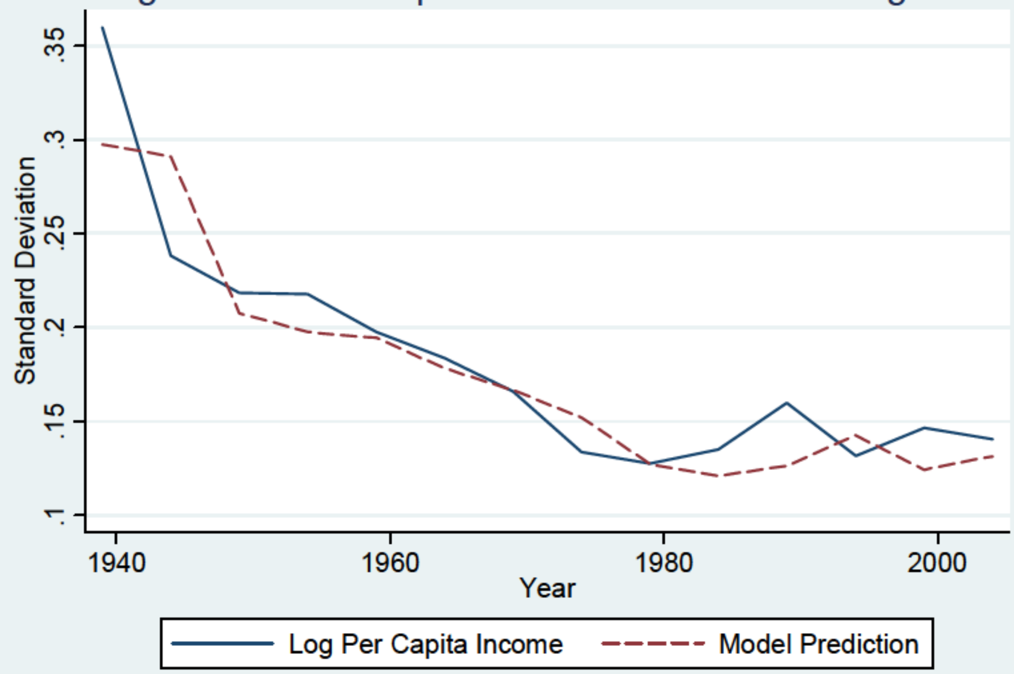
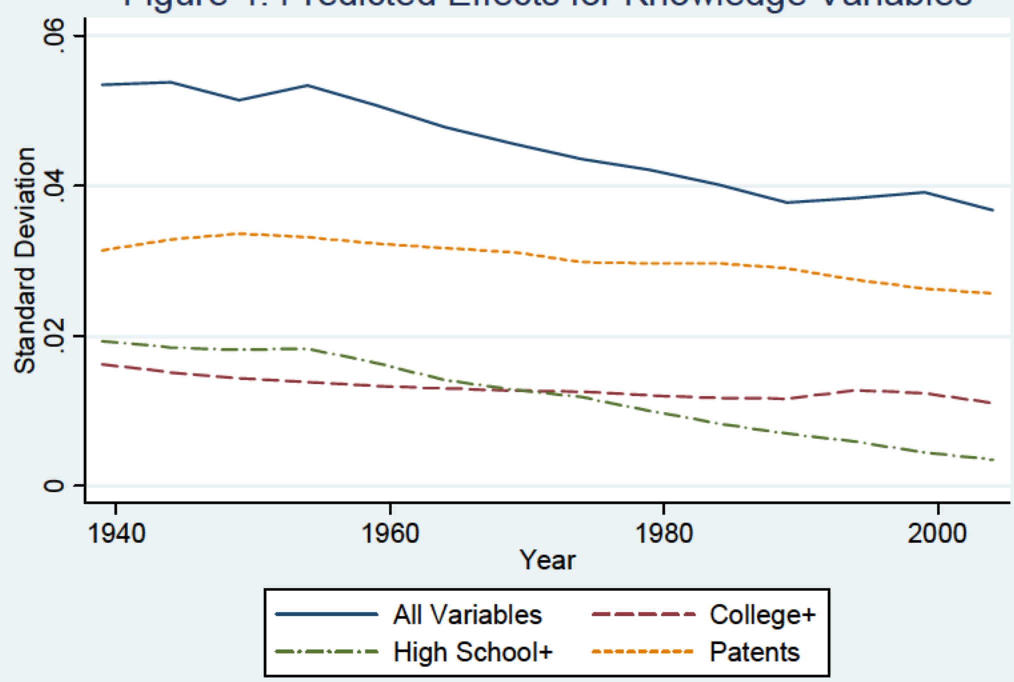


Figure 4: Predicted Effects for Knowledge Variables



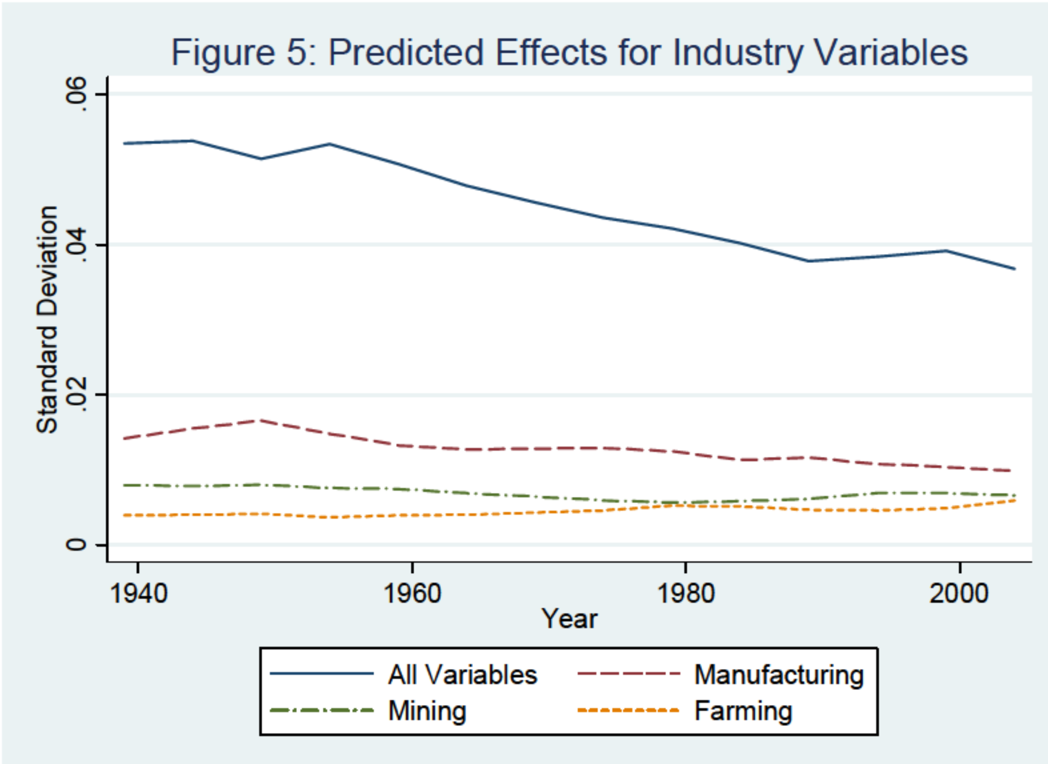


Figure 5: Predicted Effects for Industry Variables
Standard Deviation
0
.02
.04
.06
1940
1960
1980
2000
Year
All Variables
Manufacturing
Mining
Farming

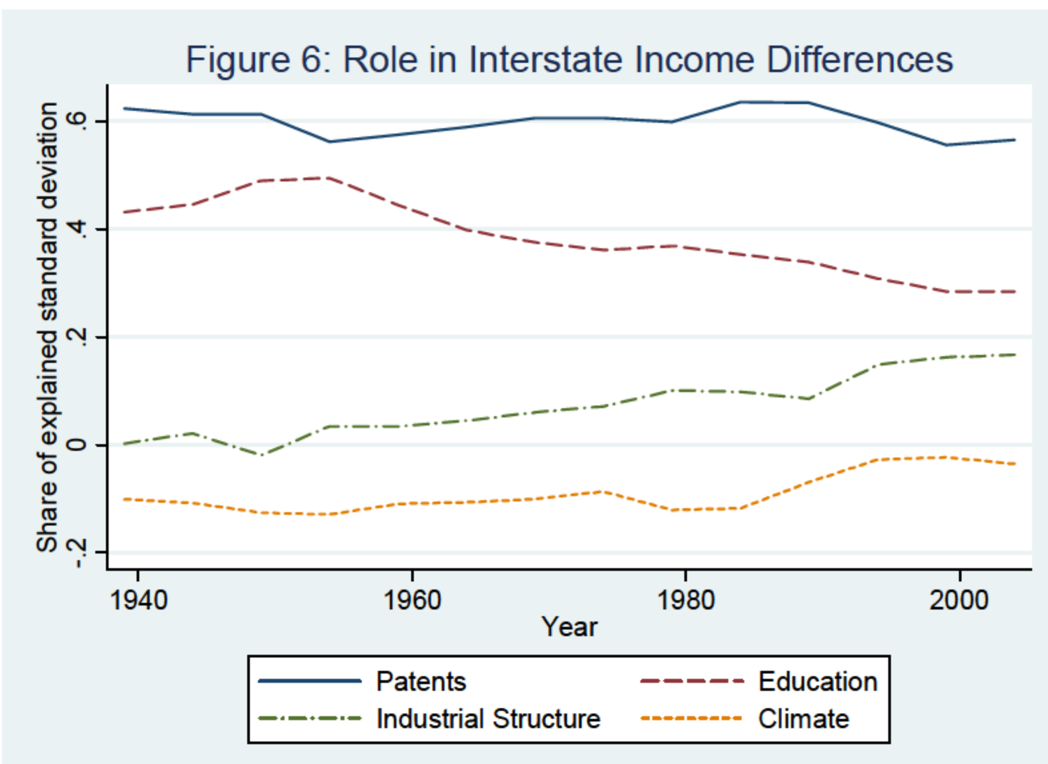


Figure 6: Role in Interstate Income Differences
Share of explained standard deviation
-.2
0
.2
.4
.6
1940
1960
1980
2000
Year
Patents
Education
Industrial Structure
Climate

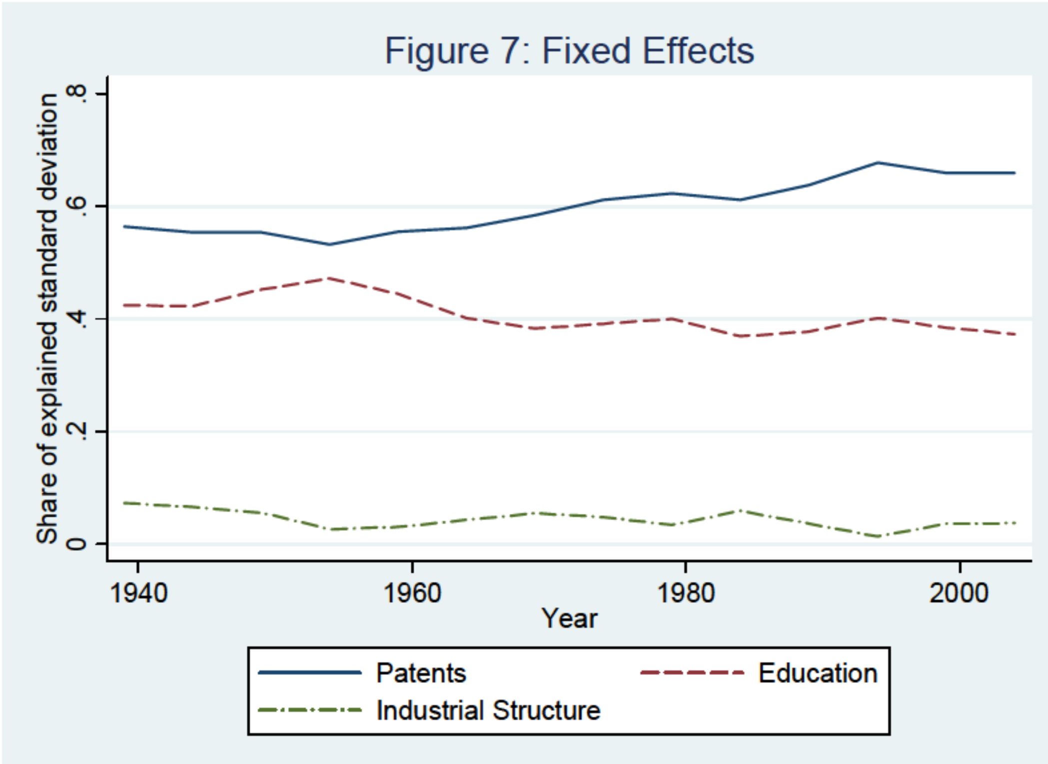


Figure 7: Fixed Effects
Share of explained standard deviation
0
.2
.4
.6
.8
1940
1960
1980
2000
Year
Patents
Education
Industrial Structure

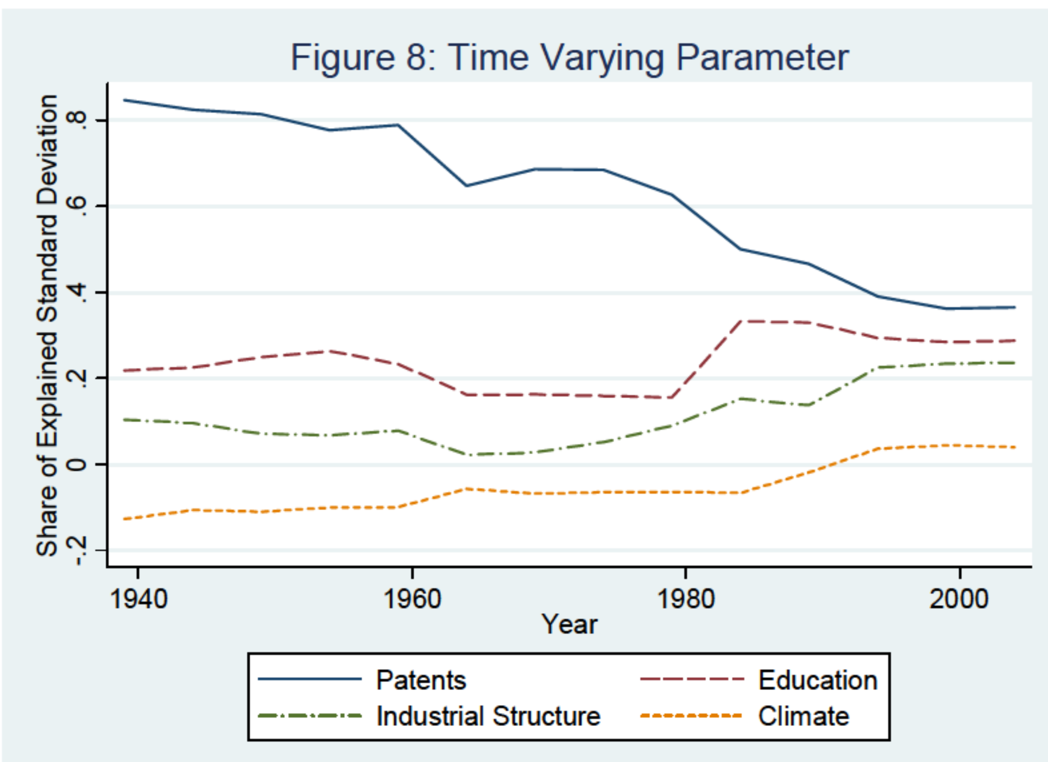


Figure 8: Time Varying Parameter
Share of Explained Standard Deviation
-.2
0
.2
.4
.6
.8
1940
1960
1980
2000
Year
Patents
Education
Industrial Structure
Climate

Figure 9: Baseline Model Lag=10

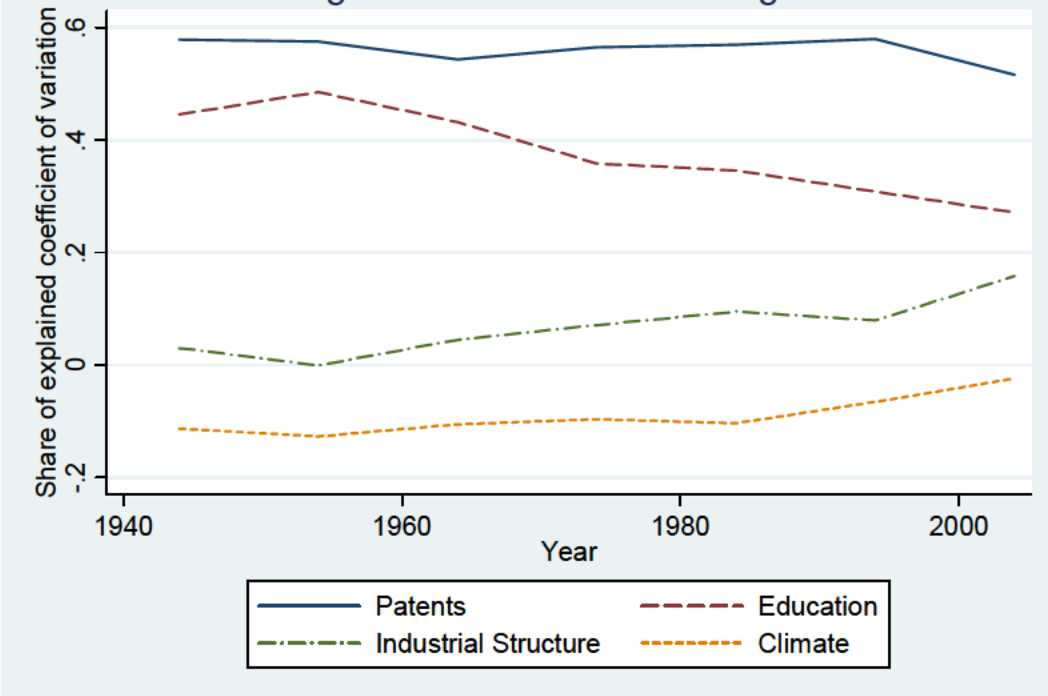


Figure 10: Baseline Model Depreciation=100%

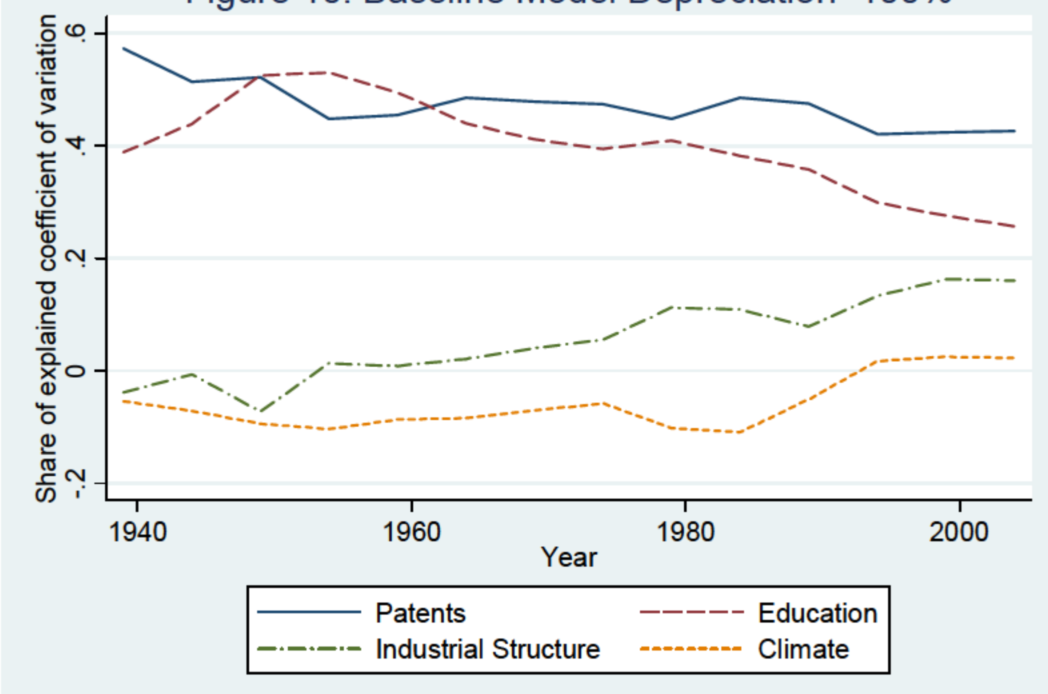


Figure 11

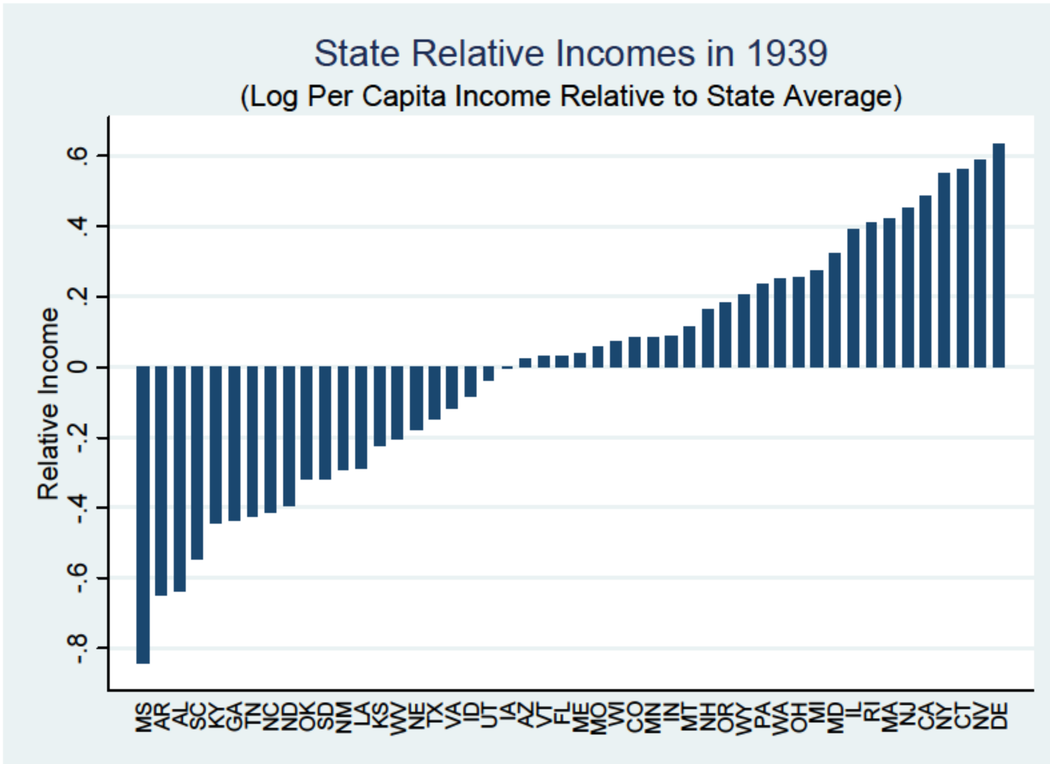


Figure 12

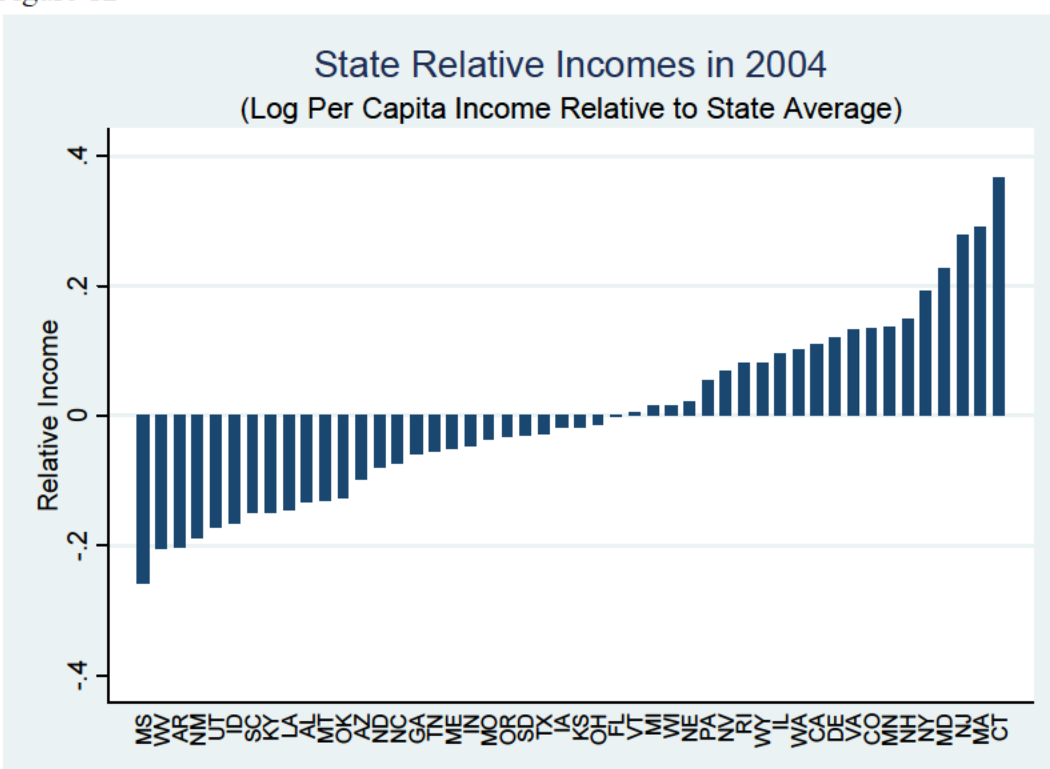


Figure 13: Baseline

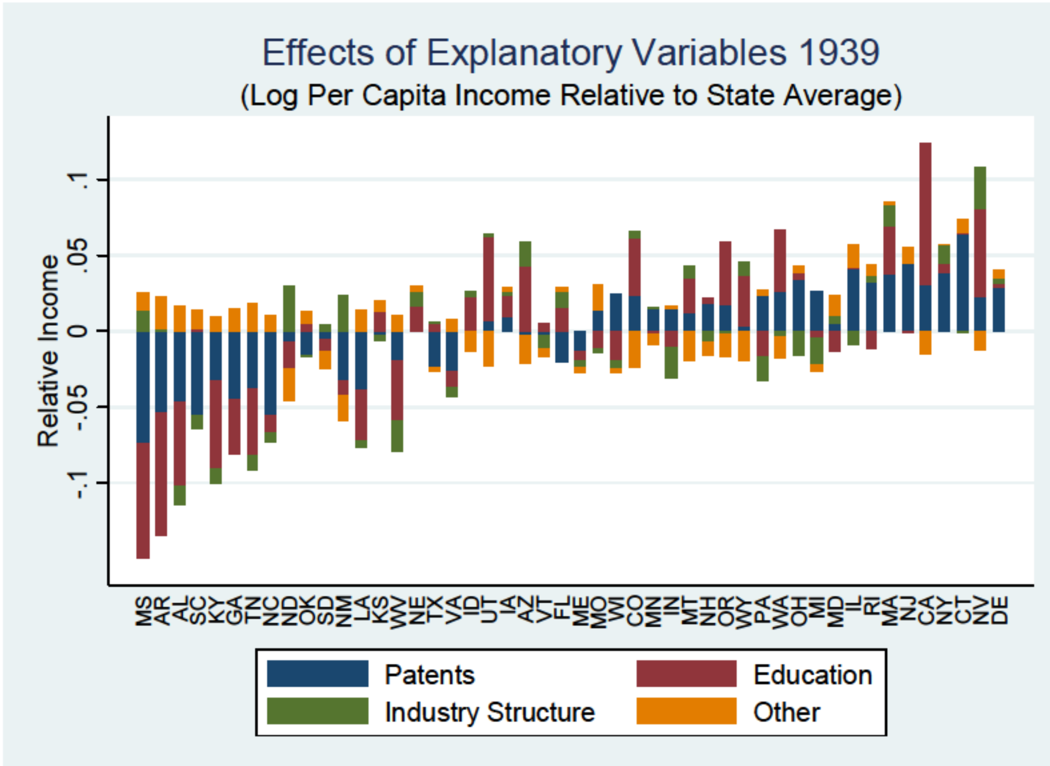


Figure 14

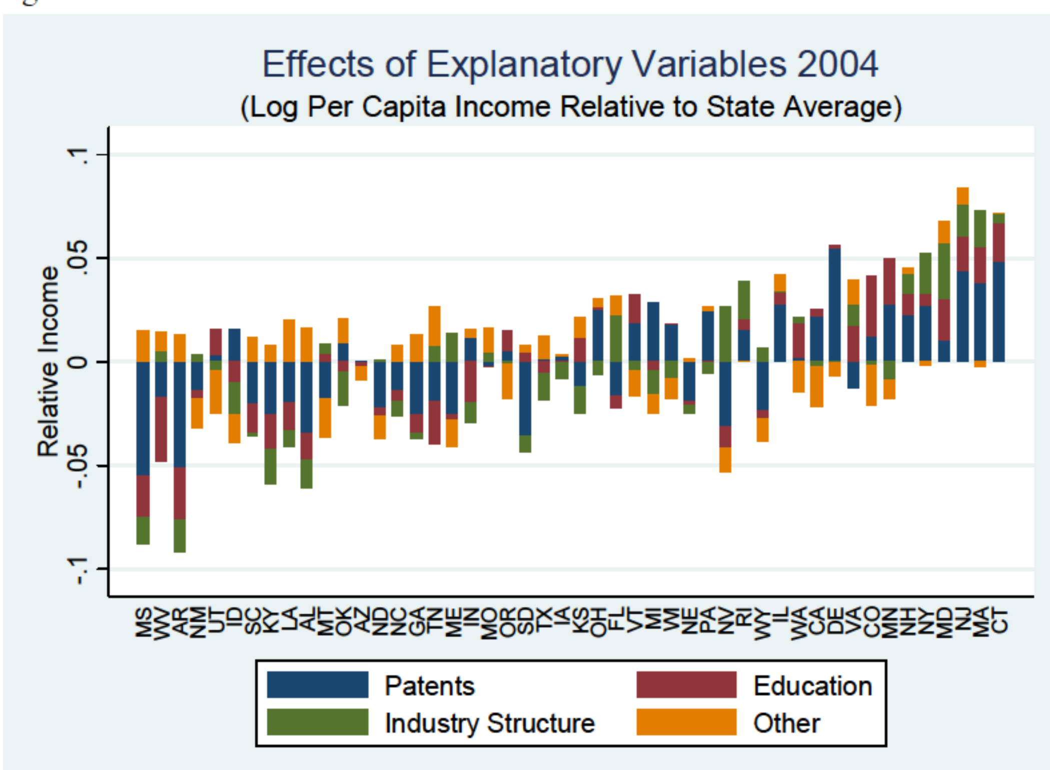


Figure 15: Baseline

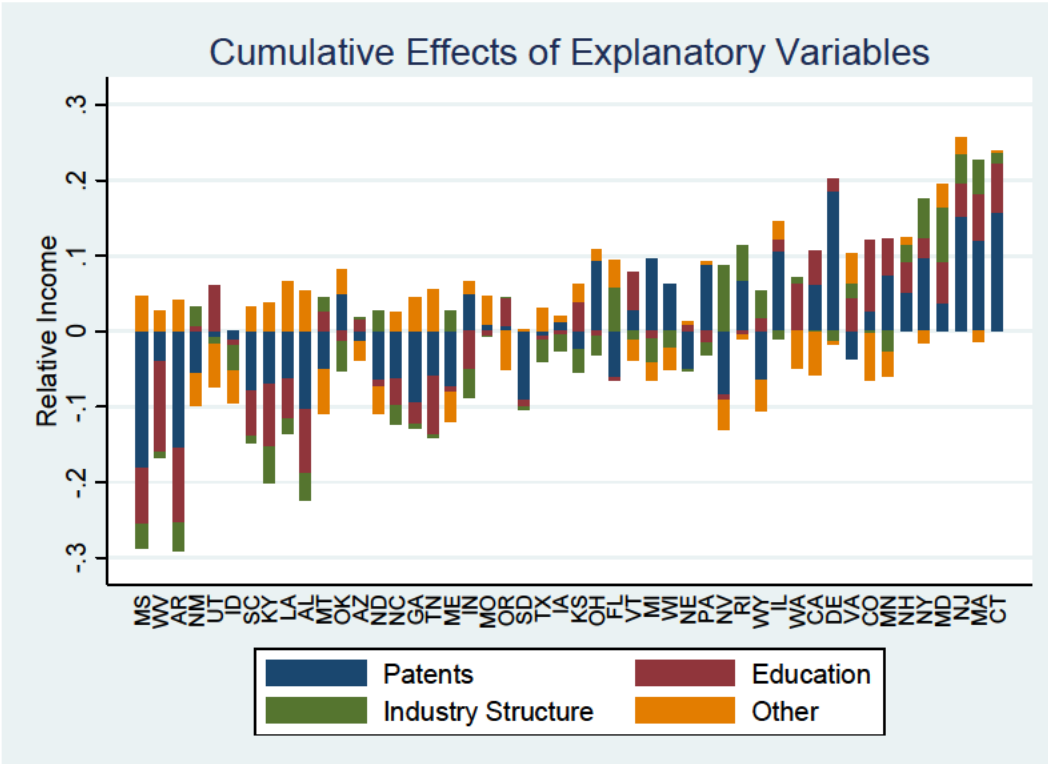


Figure 16: Fixed Effect

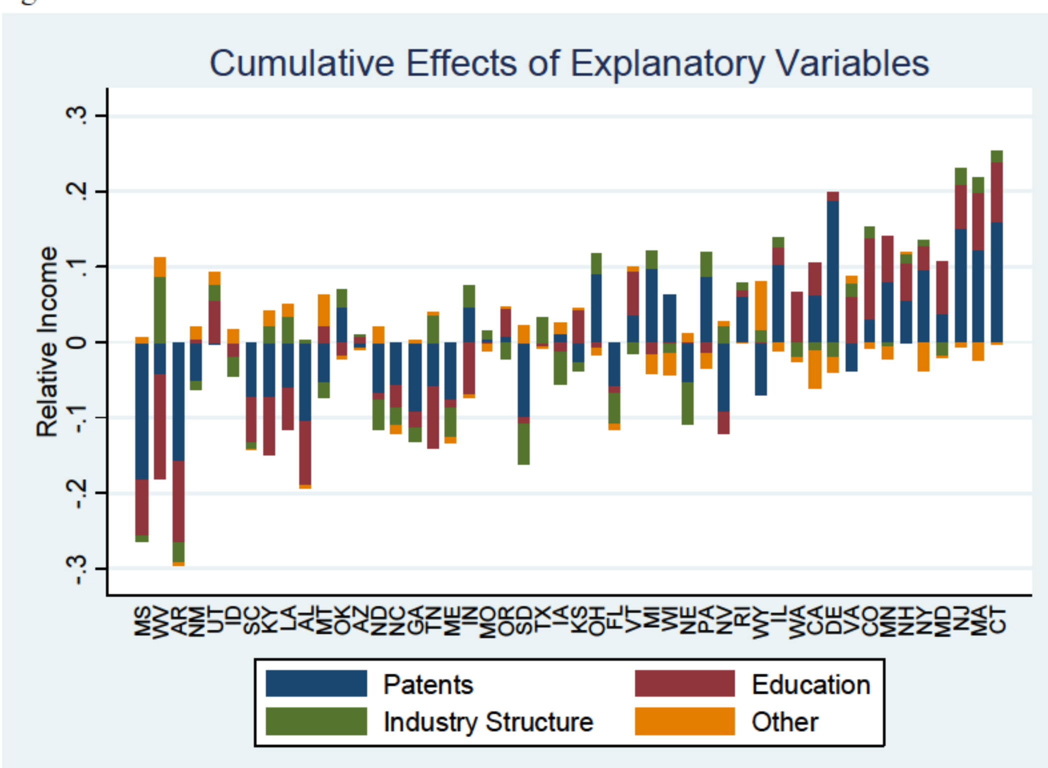


Table 1: Values of Selected Variables

State	Population (000)		Personal Income (real per capita)		Patents (per capita)		High School+ (percent)		College+ (percent)	
	1934	1999	1934	2005	1934	1999	1934	1999	1934	1999
Alabama	2,685	4,430	2,220	25,352	0 053	0 091	13 1	81 1	2 5	21 8
Arizona	428	5,024	3,789	26,241	0 114	0 298	24 8	83 1	5 7	24 2
Arkansas	1,878	2,652	1,953	23,602	0 024	0 071	12 1	78 9	1 8	17 3
California	6,060	33,499	6,254	32,285	0 440	0 501	34 7	80 4	8 5	27 1
Colorado	1,075	4,226	3,874	33,095	0 224	0 429	26 5	90 4	4 9	38 7
Connecticut	1,650	3,386	6,862	41,766	0 818	0 530	19 4	83 7	3 9	33 5
Delaware	250	775	6,798	32,605	0 848	0 538	18 7	84 5	4 2	24 0
Florida	1,585	15,759	3,629	28,855	0 146	0 165	22 0	82 7	4 2	21 6
Georgia	2,964	8,046	2,561	27,292	0 048	0 164	15 6	80 7	2 8	21 5
Idaho	473	1,276	4,237	24,567	0 070	0 959	25 3	84 8	3 9	20 8
Illinois	7,772	12,359	5,304	31,833	0 559	0 302	19 6	85 4	3 8	25 6
Indiana	3,319	6,045	3,778	27,611	0 367	0 238	19 7	82 9	3 1	18 4
Iowa	2,510	2,918	2,828	28,402	0 148	0 255	24 2	89 7	3 7	21 7
Kansas	1,868	2,678	2,999	28,436	0 094	0 162	23 1	87 6	3 8	26 5
Kentucky	2,722	4,018	2,455	24,911	0 061	0 113	12 6	78 2	2 5	19 8
Louisiana	2,202	4,461	2,764	24,999	0 047	0 108	15 5	78 3	2 9	20 7
Maine	829	1,267	4,376	27,520	0 107	0 096	24 4	88 9	2 6	22 9
Maryland	1,710	5,255	5,443	36,303	0 291	0 287	16 1	84 7	3 8	34 7
Massachusetts	4,305	6,317	6,414	38,645	0 519	0 557	25 2	85 1	4 6	31 0
Michigan	4,798	9,897	4,760	29,404	0 478	0 372	20 1	85 5	3 4	21 3
Minnesota	2,695	4,873	3,767	33,184	0 210	0 544	20 3	91 1	3 5	32 0
Mississippi	2,050	2,828	1,825	22,362	0 015	0 066	9 6	78 0	2 6	19 2
Missouri	3,784	5,562	3,863	27,948	0 230	0 167	18 3	85 0	3 4	23 0
Montana	545	898	3,831	25,357	0 090	0 140	24 5	88 8	4 2	24 0
Nebraska	1,382	1,705	2,721	29,576	0 101	0 112	24 0	89 3	3 8	20 4
Nevada	98	1,935	5,688	30,990	0 133	0 152	29 1	86 4	6 0	20 2
New Hampshire	480	1,222	5,005	33,626	0 304	0 533	22 0	86 5	3 5	27 2
New Jersey	4,089	8,360	6,019	38,224	0 778	0 477	17 6	87 4	4 2	30 5
New Mexico	461	1,808	2,593	23,976	0 037	0 187	18 6	80 9	3 5	24 5

Table 1: Values of Selected Variables (continued)

State	Population (000)		Personal Income (real per capita)		Patents (per capita)		High School+ (percent)		College+ (percent)	
	1934	1999	1934	2005	1934	1999	1934	1999	1934	1999
New York	13,253	18,883	7,129	35,039	0 581	0 324	17 8	81 9	4 6	26 9
North Carolina	3,304	7,949	2,657	26,862	0 044	0 218	17 7	79 8	3 6	23 9
North Dakota	672	644	1,910	26,726	0 046	0 104	18 5	84 9	3 0	22 3
Ohio	6,751	11,335	4,781	28,560	0 558	0 296	20 8	86 1	3 8	25 5
Oklahoma	2,391	3,437	2,625	25,498	0 102	0 144	20 1	83 5	4 0	23 7
Oregon	985	3,394	4,621	28,058	0 214	0 323	28 1	86 2	4 8	26 8
Pennsylvania	9,795	12,264	5,069	30,512	0 357	0 306	16 5	86 1	3 6	23 9
Rhode Island	675	1,040	6,297	31,350	0 410	0 251	16 5	80 9	3 8	26 8
South Carolina	1,760	3,975	2,209	24,889	0 026	0 141	17 9	78 6	4 3	20 9
South Dakota	682	750	1,942	28,073	0 067	0 088	20 5	88 7	3 2	25 6
Tennessee	2,784	5,639	2,572	27,356	0 078	0 152	14 9	79 1	2 6	17 7
Texas	6,053	20,558	3,042	28,160	0 099	0 294	21 7	78 2	3 7	24 4
Utah	522	2,203	3,266	24,376	0 121	0 308	30 8	91 0	5 4	27 9
Vermont	357	605	4,013	29,098	0 157	0 562	23 2	89 3	3 4	28 3
Virginia	2,485	7,000	3,340	33,063	0 093	0 149	18 0	87 3	3 6	31 6
Washington	1,610	5,843	4,642	32,080	0 232	0 313	28 3	91 2	4 7	28 6
West Virginia	1,771	1,812	3,298	23,575	0 088	0 082	14 4	75 1	2 9	17 9
Wisconsin	3,054	5,333	3,991	29,418	0 383	0 314	17 3	86 8	3 2	23 6
Wyoming	233	492	4,290	31,386	0 150	0 106	27 9	90 7	4 2	22 3
Average	2,621	5,763	3,965	29,230	0 233	0 273	20 6	84 5	3 8	24 6

*The GDP price deflator, base year=2000, was used to calculate real values

Table 1 (continued)

State	Tax Rate (proportion)		Highway Capital (real per capita)		Business Failure Rate (proportion)		Bank Deposits (real per capita)	
	1934	1999	1934	1999	1934	1999	1934	1999
Alabama	0.0474	0.0594	655	1,387	0.00335	0.00416	9,690	11,800
Arizona	0.0721	0.0624	1,070	1,373	0.00102	0.00835	42,625	7,666
Arkansas	0.0606	0.0820	2,139	1,568	0.00335	0.00580	8,381	11,466
California	0.0365	0.0724	399	606	0.01002	0.01232	43,235	9,051
Colorado	0.0473	0.0507	601	1,199	0.00523	0.00920	21,957	9,501
Connecticut	0.0334	0.0741	513	2,041	0.01017	0.00260	29,148	15,344
Delaware	0.0606	0.0906	1,317	2,868	0.00159	0.00091	33,401	68,013
Florida	0.0512	0.0560	665	1,320	0.00267	0.00240	39,266	11,043
Georgia	0.0431	0.0588	709	1,531	0.00300	0.00216	11,980	10,723
Idaho	0.0425	0.0745	742	1,912	0.00310	0.00489	14,768	7,289
Illinois	0.0255	0.0568	689	1,468	0.00566	0.00698	22,777	15,372
Indiana	0.0478	0.0629	438	1,342	0.00337	0.00133	16,581	10,032
Iowa	0.0645	0.0664	740	2,256	0.00331	0.00107	13,817	13,161
Kansas	0.0462	0.0647	1,680	2,156	0.00198	0.01042	13,996	11,628
Kentucky	0.0550	0.0785	442	2,318	0.00226	0.00128	10,080	11,627
Louisiana	0.0666	0.0625	853	1,863	0.00175	0.00386	15,686	9,586
Maine	0.0554	0.0819	824	1,444	0.00676	0.00316	13,376	10,102
Maryland	0.0328	0.0569	509	1,291	0.00606	0.00621	20,641	9,578
Massachusetts	0.0279	0.0681	252	1,962	0.00960	0.00324	25,733	20,174
Michigan	0.0493	0.0785	476	925	0.00393	0.00365	20,198	9,780
Minnesota	0.0526	0.0851	953	1,468	0.00459	0.01081	18,582	13,657
Mississippi	0.0480	0.0803	397	1,776	0.00343	0.00276	8,388	9,827
Missouri	0.0335	0.0599	1,112	1,442	0.00331	0.00552	15,740	12,751
Montana	0.0408	0.0656	824	3,299	0.00442	0.00552	15,456	8,923
Nebraska	0.0442	0.0590	811	2,352	0.00562	0.00400	12,749	14,638
Nevada	0.0552	0.0602	3,971	1,538	0.00261	0.01201	62,158	8,237
New Hampshire	0.0467	0.0288	407	1,332	0.00324	0.00451	26,508	15,034
New Jersey	0.0381	0.0575	908	1,674	0.00956	0.00434	19,924	14,244
New Mexico	0.0665	0.0837	1,142	1,868	0.00146	0.00759	17,588	6,929

Table 1 (continued)

State	Tax Rate (proportion)		Highway Capital (real per capita)		Business Failure Rate (proportion)		Bank Deposits (real per capita)	
	1934	1999	1934	1999	1934	1999	1934	1999
New York	0.0303	0.0625	365	1,302	0.01188	0.00520	46,101	20,627
North Carolina	0.0582	0.0710	473	1,403	0.00364	0.00310	10,050	12,719
North Dakota	0.0600	0.0674	442	2,767	0.00150	0.00581	12,448	14,570
Ohio	0.0335	0.0597	253	1,295	0.00571	0.00595	14,735	11,534
Oklahoma	0.0579	0.0671	887	1,554	0.00350	0.00580	13,024	9,721
Oregon	0.0528	0.0589	1,138	1,381	0.01012	0.00771	21,993	7,793
Pennsylvania	0.0392	0.0630	352	1,196	0.00415	0.00535	16,667	12,946
Rhode Island	0.0312	0.0663	550	1,937	0.01356	0.00274	27,278	11,930
South Carolina	0.0588	0.0672	874	1,145	0.00246	0.00359	6,503	7,742
South Dakota	0.0838	0.0472	850	3,001	0.00214	0.01011	11,897	15,727
Tennessee	0.0445	0.0513	1,133	1,701	0.00473	0.00497	13,483	11,784
Texas	0.0533	0.0463	933	1,359	0.00263	0.00733	23,024	9,064
Utah	0.0708	0.0738	673	1,908	0.00809	0.00271	19,917	8,632
Vermont	0.0665	0.0887	1,893	1,600	0.00342	0.00156	16,786	11,549
Virginia	0.0464	0.0565	894	1,807	0.00517	0.00396	15,261	10,522
Washington	0.0538	0.0699	805	1,520	0.00784	0.00695	23,265	9,218
West Virginia	0.0496	0.0838	607	2,968	0.00656	0.00558	8,791	11,414
Wisconsin	0.0513	0.0803	918	1,108	0.00539	0.00501	15,475	12,454
Wyoming	0.0520	0.0474	2,326	5,655	0.00327	0.00719	19,695	12,861
Average	0.0497	0.0660	888	1,796	0.00484	0.00524	20,017	12,708

*The GDP price deflator, base year=2000, was used to calculate real values.

Table 2: Endogeneity Tests

Lag	All	Stock of Patents	Educational Attainments	Business Failure Rate	Tax Rate	Highway Capital	Banking Deposits
1	0.000	0.000	0.000	0.000	0.000	0.076	0.000
2	0.000	**0.331**	0.002	0.000	0.000	**0.330**	0.007
3	0.000	**0.621**	0.000	0.005	0.001	**0.205**	**0.458**
4	0.002	0.009	**0.297**	0.034	0.003	**0.734**	**0.112**
5	**0.149**	**0.583**	**0.181**	**0.118**	**0.145**	**0.553**	**0.121**
6	**0.369**	0.041	**0.779**	**0.341**	0.765	**0.940**	**0.540**
7	**0.161**	**0.141**	**0.057**	**0.390**	**0.799**	**0.819**	**0.371**
8	**0.768**	**0.899**	**0.735**	**0.150**	**0.991**	**0.699**	**0.180**

Table 3: Regression results

	Baseline	Fixed Effect	Time	Varying	Parameters	Baseline	Baseline
	Lag=5	Lag=5	1939-1959	1964-1979	1984-2004	Lag=10	100% Depreciation
Lagged Income	0 673	0 557	0 630	0 630	0 630	0 434	0 665
	(31 06)**	(21 43)**	(25 35)**	(25 35)**	(25 35)**	(13 29)**	(28 95)**
Manufacturing	-0 0224	0 0110	-0 00573	-0 0214	-0 0344	-0 0336	-0 0312
Share	(-3 21)**	(0 91)	(-0 57)	(-1 47)	(-2 47)**	(-3 08)**	(-4 25)**
Farm Share	-0 00452	-0 00961	-0 0109	0 00269	-0 00638	-0 00896	-0 00566
	(-1 51)	(-1 68)	(-1 37)	(0 45)	(-1 57)	(-1 84)	(-1 91)
Mining Share	-0 00477	0 00744	-0 00173	-0 00965	-0 0108	-0 00731	-0 00392
	(-2 23)*	(1 37)	(-0 57)	(-2 10)*	(-2 48)*	(-2 20)*	(-1 84)*
Heating Days	0 00944	na	-0 0177	-0 00439	0 0202	0 0205	0 0248
	(1 01)		(-0 92)	(-0 24)	(1 42)	(1 36)	(2 84)**
Cooling Days	0 0135	na	0 0167	0 00831	0 107	0 0236	0 0140
	(2 33)*		(1 60)	(0 73)	(1 16)	(2 55)*	(2 43)*
Precipitation	0 201	na	-0 0143	-0 00679	0 0340	0 0323	0 0291
	(2 11)*		(-0 69)	(-0 33)	(2 27)*	(2 10)*	(3 01)**
High School+	0 0744	0 0824	0 0670	0 0244	0 0378	0 120	0 103
	(3 08)**	(2 31)*	(1 87)	(0 42)	(0 46)	(3 18)**	(4 26)**
College+	0 0624	0 109	0 0278	0 0264	0 0959	0 103	0 0497
	(3 61)**	(3 78)**	(0 83)	(0 78)	(3 19)**	(3 75)**	(2 80)**
Stock	0 0405	0 0560	0 0751	0 0417	0 0367	0 0619	0 0323
of Patents	(6 17)**	(4 39)**	(5 64)**	(3 37)**	(3 63)**	(5 88)**	(5 30)**
Business Failure Rate	0 00304	-0 00400	0 00259	0 0128	0 00567	0 00320	0 00112
	(0 76)	(-0 89)	(0 36)	(1 55)	(0 81)	(0 48)	(0 28)
Tax Rate	-0 0155	-0 0106	-0 0174	-0 0360	-0 0233	-0 0194	-0 0163
	(-1 35)	(-0 63)	(-0 86)	(-1 69)	(-1 13)	(-1 08)	(-1 42)
Highway Capital	0 00880	0 0215	0 0341	0 0137	-0 00915	0 00449	-0 00458
	(1 05)	(1 69)	(2 81)*	(0 71)	(-0 54)	(0 35)	(-0 74)
Banking	-0 00590	-0 0136	-0 0195	-0 00381	-0 00557	-0 00222	0 00739
Deposits	(-0 064)	(-0 98)	(-1 01)	(-0 19)	(-0 63)	(-0 15)	(0 83)
Observations	672	672		672		336	672
R-squared	0 998	0 998		0 998		0 998	0 998

Value of t statistics in parentheses
* significant at 5%; ** significant at 1%

“Inventive capacity and activity—including R&D investment, a science-oriented workforce, collaboration, and patented output—are realized most completely in the nation’s metropolitan areas.”

Patenting Prosperity:

Invention and Economic Performance in the United States and its Metropolitan Areas

Jonathan Rothwell, José Lobo, Deborah Strumsky, and Mark Muro

An analysis of national and metropolitan area invention from 1980 to 2012, using a new comprehensive database of patents, reveals:

- **The rate of patenting in the United States has been increasing in recent decades and stands at historically high levels.** Growth in patent applications slowed after the IT bubble and the Great Recession, but the rate of patenting by U.S. inventors is at its highest point since the Industrial Revolution. Moreover, patents are of objectively higher value now than in the recent past and more evenly dispersed among owners than in previous decades. Still, the United States ranks just ninth in patents per capita using appropriate international metrics, as global competition has increased.

- **Most U.S. patents—63 percent—are developed by people living in just 20 metro areas, which are home to 34 percent of the U.S. population.** Reflecting the advantages of large metropolitan economies, 92 percent of U.S. patents are concentrated in just 100 metro areas, with 59 percent of the population. For patents applied for from 2007 to 2011, the metro areas with the highest number per capita are San Jose; Burlington, VT; Rochester, MN; Corvallis, OR; and Boulder, CO.

- **Inventions, embodied in patents, are a major driver of long-term regional economic performance, especially if the patents are of higher quality.** In recent decades, patenting is associated with higher productivity growth, lower unemployment rates, and the creation of more publicly-traded companies. The effect of patents on growth is roughly equal to that of having a highly educated workforce. A low-patenting metro area could gain $4,300 more per worker over a decade’s time, if it became a high-patenting metro area.

- **Research universities, a scientifically-educated workforce, and collaboration play an important role in driving metropolitan innovation.** Metro areas with high patenting rates are significantly more likely to have graduate programs in science, especially high-ranking programs, even adjusting for tech sector employment. A high share of college graduates from science fields is also strongly related to higher patenting levels and rates. Additionally, metro areas that collaborate more on patenting, patent more.

- **Patents funded by the U.S. government tend to be of especially high quality, and federal small business R&D funding is associated with significantly higher metropolitan productivity growth.** The U.S. government supports more basic research than the private sector, and so outputs are more likely to be scientific publications than patents. Still, the patents and other research projects that are supported appear to be highly valuable to both regions and society.

For all the success of the United States, the value of invention is not evenly shared across regions because of the clustering of assets like science majors, tech sector workers, and leading research universities. As a result, metropolitan, state, and federal policy makers need to consider ways to foster these attributes more broadly and generally support research and development, as discussed below. The report also recommends reforms to patent law to protect startups and other productive companies from frivolous and expensive legal challenges.

Introduction

Innovation is central to economic growth.[1] Arguably, the most valuable innovations have been embodied in technologies that perform work, such as the provision of energy or health, product assembly, information storage and retrieval, and transportation, to name just a few functions. Such technologies have radically transformed the way humans live for the better and, along with political reforms, have allowed hundreds of millions of men and women descended from serfs, slaves, and peasants to obtain a measure of health and affluence previously available only to elites.[2]

In the midst of a weak recovery from a particularly severe recession, many people are wondering whether the United States is in a state of decline, lacking the dynamism it once had.[3] According to one recent survey, more Americans think the nation's best days are in the past, not the future.[4] Among the long-run drivers of innovation, economists have been identified factors such as education and political institutions that enforce basic rights and treat people as equals.[5] There are reasons to be concerned: The growth rate of adults obtaining a college education has slowed over the last three decades, test scores are low compared to other developed countries, income inequality has increased, and U.S. political institutions have become ideologically polarized.[6] Moreover, some argue that U.S. inventive output is flagging in the face of other related challenges, including global competition, increasing technological complexity, and weak public sector support relative to other countries.[7]

More fundamentally, the United States still ranks very high globally on a number of important measures of innovative capacity, though other developed countries have caught up or overtaken it. One study rates the United States fourth in the world in terms of innovative capacity but notes that it ranks near the bottom on changes over the previous ten years in the underlying variables.[8] On the weaker side, using internationally-oriented patent applications filed from 2000 to 2010 per resident, the United States ranks somewhat lower at ninth, and it is just 13th on science and engineering publications per capita.[9] More positively, the United States ranks third on GDP per worker, behind only Luxembourg and oil-rich Norway.[10] On R&D spending per capita, it ranks second, behind only Finland.[11] Finally, according to the Leiden Ranking (from Leiden University in the Netherlands), all ten of the world's top research universities are in the United States and 43 of the top 50, led by MIT, Princeton, Harvard, and Stanford.[12] All of these factors play a role in American innovation.

The focus of this report is on inventive activity, which yields enormous benefits to society that go well beyond the gains from inventors and producers.[13] One measure of inventive activity—the number of patents granted per person—has been increasing in the United States, alongside research and development.[14] Some scholars have even suggested that too many patents have been granted and attribute an increase to the declining rigor of approval standards.[15] Yet, there is a large body of compelling evidence showing that most patents do actually represent valuable inventions, especially "high quality" patents—meaning those that are highly cited or those that advance more intellectual property claims.[16] Despite wide variation in value, economists have calculated that the average patent is worth over half a million dollars in direct market value (and considerably more in social value as the technology and its ideas become diffused).[17] These estimates are consistent with recent patent sales reported in the media from Eastman Kodak, Motorola, Nortel, and Nokia, which have ranged $477,000 to $760,000 per patent, and even single patents from relatively unknown companies list patent prices at an online website for $1 million.[18] Still, some are sold for much less, and others never generate any market or social value or become obsolete after a few years. For example, despite the large legal costs of obtaining a patent, 16 percent of patents are allowed to expire after just four years because the owners refuse to pay even a $900 maintenance fee.[19] In any case, there is evidence that patent value is increasing. One indication is that scientific and technical research is increasingly collaborative in the United States and globally, and this appears to be leading to more valuable patents and publications.[20] Another is that corporate income from manufacturing sector royalties—which come largely from the licensing of patents—increased by 89 percent from 1994 to 2009, almost double the growth rate of patents granted to domestic inventors.[21]

However measured, inventive capacity and activity—including R&D investment, a science-oriented workforce, collaboration, and patented output—are realized most completely in the nation's metropolitan areas. Their overlapping social and infrastructure networks, linking and fostering interactions among individuals and businesses have made cities and their surrounds, since their very beginnings, the privileged settings for invention and innovation. As Adam Smith argued in the 18th Century, the large population size of metropolitan regions fosters trade and specialization, which increases productivity and frees people up for research activity.[22] Moreover, metropolitan areas facilitate the matching of workers to firms, learning between specialists, and the sharing of suppliers, customers, and regional assets.[23] Consequently, patenting activity in the United States has always been largely an urban phenomenon and is highly concentrated in large metro areas today.[24] This is also true globally: 93 percent of the world's recent patent applications were filed by inventors living in metropolitan areas with just 23 percent of the world's population.[25]

While U.S. invention remains a global force, a survey of the innovation related literature reveals that the country needs to work out a few crucial problems if it is to realize its potential for economic and social progress. First, while R&D spending continues to increase at roughly the same rate as GDP, there is evidence that inventions are becoming more expensive, more difficult, and more internationally competitive such that an even deeper commitment will be needed in both the near term and thereafter. Moreover, as the nation addresses its public finance problems, there will be pressure to cut R&D support. In fact, the federal commitment has already been shrinking in that spending has not kept up with GDP. This trend should be reversed. The public sector has a vital role to play in supporting innovation and invention.

Second, the nation's unequal access to high quality schooling means that too few—especially those born into lower income families—are academically prepared to meaningfully contribute to invention, and that not only delimits economic opportunity, it deprives the innovation system of a large number of people who might otherwise make or commercialize important discoveries.[26] This was not the case during America's most productive decades of the industrial revolution—after the Civil War and into the early 20th Century—when patenting was "democratized" and mostly done by blue collar workers, many of whom were not professional inventors.[27]

Third, while the patent system is not fundamentally broken, neither is it functioning as efficaciously as possible. Some have concluded that the entire system should be abolished based on such considerations.[28] That would be a big mistake. Recognizing that ideas can be easily transmitted, copied, and reproduced, the nation's founders, including Madison and Jefferson, took for granted that the patent system was an obvious and necessary means to promote invention.[29] All but a tiny fraction of the early industrial revolution's great inventions were patented.[30] Of 5,000 start-up companies founded in 2004, the share receiving venture capital financing—an indicator of market viability—was 14 times higher for companies with patents.[31] Comparative economic studies of patent systems tend to verify the Madisonian view, and industries that rely more on patenting are more competitive than those that do not.[32] The increase in formal litigation is a problem, but it has roughly grown at the same pace as the increase in patents.[33]

Still, in patent law's delicate balancing of incentives to invent with competition, the academic community has largely concluded that the balance leans too heavily in favor of intellectual property protection, especially with respect to the U.S. Patent and Trademark Office (USPTO), which is regarded by some scholars as less rigorous than the European Patent Office (EPO) or even the Japanese Patent Office (JPO).[34] Concerns include, but are not limited to, a decline in the quality of patents being issued, the granting of excessively broad claims over questionable subject matter, the granting of patent protection to "nature," to functions, or otherwise inappropriate subject matter, the difficulty of entering markets with many patents, and abuse of the legal system to extract rewards for infringement without contributing to innovation. The growing popularity of open-source software is something of a rebuke to the patent system.[35]

It should be noted that Congress and the USPTO are aware of these concerns, and the pendulum may be swinging in the other direction.[36] The American Invents Act, signed into law in 2011, was designed, in part, to address them by taking steps to increase examination quality and make abusive litigation less likely. Likewise, a 2012 Supreme Court decision clarified limitations on patenting laws of nature.[37] A similar clarification of rules with respect to software patents would be valuable in clarifying that functions, as opposed to the means of performing functions through software code or processes, should not be granted patents.[38] Moreover, there is disturbing evidence that non-producing entities (NPEs or firms deemed "trolls") are taxing productivity activity by buying up large patent portfolios with the sole purpose of suing producers. Such is the problem that the Department of

Justice and the Federal Trade Commission hosted a recent workshop on the anti-competitive implications of these trends.[39] More specifically, survey-based evidence reveals that trolls are extracting billions of dollars (as much as $29 billion in 2011) in payment, and that they often target small players, often startups, imposing huge cost burdens, while suppressing production.[40] In 2011, they initiated an estimated 40 percent of lawsuits, up from 22 percent in 2007.[41] Other studies have shown that NPEs account for most cases involving frequently litigated patents, and that NPEs tend to acquire very high-value patents for that purpose.[42] Settlements reached out of court often do not result in any public records, but there is now abundant anecdotal evidence and a growing sense of outrage that non-producers are effectively extorting companies on a large scale.[43] This needs to be resolved.

Finally, the nation must wrestle with the geography of innovation. As economist Enrico Moretti has persuasively argued, highly educated metropolitan areas have grown increasingly apart on measures of income and even health than less educated metropolitan areas in recent decades, reflecting the importance of industry clusters and urban economics in a technologically-infused world that increasingly rewards education.[44] Less educated areas where temporarily bolstered by the housing bubble because of their cheap land value and labor costs, and even highly educated areas were often seduced into supporting large and wasteful public investments in consumer projects—like new sports complexes.[45] A better use of local, state, and—when appropriate—federal dollars would be on shoring up a region's market failures or otherwise helping to solve pressing needs for things like educated workers, investment capital, infrastructure, or research institutions. For example, a remarkable study from Finland found that the opening of three technical research universities boosted patenting there by 20 percent, with large effects on engineering education near the universities.[46]

With these concerns in mind, this report examines the importance of patents as a measure of invention to economic growth and explores why some areas are more inventive than others. Why should we expect there to be a relationship between patenting and urban economic development? As economist Paul Romer has written, the defining nature of ideas, in contrast to other economic goods, is that they are non-rival: their use by any one individual does not preclude others from using them.[47] Although useful ideas can be freely transmitted and copied, the patent system guarantees, in principle, temporary protection from would-be competitors in the marketplace (i.e. excludability). Thus, one would expect regions to realize at least some of the value of invention, as has been shown for individual inventors and companies that patent.[48] Yet there is no guarantee that patents generated in a specific location will generate wealth in that same location—a set of conditions (the presence of a skilled and diverse labor force, an "ecosystem" of businesses providing complementary goods and services, financing and marketing capabilities among them) have to be met for invention to be commercialized. Research has established that patents are correlated with economic growth across and within the same country over time.[49] Yet, metropolitan areas play a uniquely important role in patenting, and the study of metropolitan areas within a single large country—the United States—allows one to isolate the role of patents from other potentially confounding factors like population size, industry concentration, and workforce characteristics.

After briefly summarizing the methods used to address these issues, the report proceeds with an analysis of U.S. trends in patenting, with a view to addressing the vibrancy, or lack thereof, in U.S. economic performance. It also assesses how the quality of patents has changed over time and depends on the source of funding. Then the analysis turns to the role of metro areas in invention and the effects that invention has on regional economic development, measured by productivity and unemployment. This study also goes deeper to explore the role of universities and other local institutions as well as science-educated workforce in accounting for why some areas patent more than others. The report concludes with reform proposals to protect innovative companies from unwarranted legal costs and boost innovation. It also explains why public investments in R&D and deployment are needed to realize the country's full potential to innovate, and how educational inequality is hindering U.S. economic performance.

Methods

Source and Description of Patent Data

The USPTO maintains patent records from its founding in 1790. Yet, for research purposes, much of the information from previous centuries has not been digitized and thus is not readily available for research use. Starting with patents granted in1975, however, the USPTO has digitized information on inventor and assignee (patent owner) names, as well as addresses and other detailed characteristics of the patent.

More detailed methodology can be found on the report's web page at www.brookings.edu/research/reports/2013/02/patenting-prosperity-rothwell or directly at www.brookings.edu/sitecore/shell/~/media/Research/Files/Reports/2013/02/patenting prosperity rothwell/patenting-prosperity-rothwell-appendix.pdf.

Deborah Strumsky has assembled this information and organized it into what is the most up-to-date and complete research database of all patenting activity that the authors are aware of, which is why we call it the **Strumsky Patent Database**. It is similar in many respects to the COMETS database and the NBER patents database, which are both excellent resources for patent scholars.[50] Still, the Strumsky Database has some unique features listed here:

- Complete coverage of all patents—including plant and design patents—from 1975 to 2012 (March 20, 2012 for this analysis).
- Using a distinct algorithm, it links inventors to their metropolitan area of residence allowing for detailed spatial analysis (COMETS offers a different version of this).[51] A metropolitan area time series is thereby available.
- It provides a large number of "quality" metrics for each patent. Those emphasized in this report are claims and citations. **Claims** define the patent's invention and what is legally enforceable about it; patents with multiple distinct inventions enumerate multiple claims.[52] **Citations** to a patent are made if subsequent patents utilize relevant or related knowledge, as determined by the applicant (who is legally bound to mention such references) and the examiner. Both measures are widely acknowledged as indicating value in the academic literature on patents.
- Each patent has a USPTO technology code (class number), as well as a more aggregate classification and sub-classification scheme created by Strumsky, which provides a sense of the industrial orientation of each patent.
- Patents are linked to inventors and patent owners (assignees), thereby allowing researcher to match inventor address information to assignees to calculate ownership statistics by metropolitan area and according to different technological categories.
- Government grant funding is indicated using information on the patent record.
- Universities, government agencies, foreign and domestic individuals and corporations are identified as distinct categories of assignees.

Patent data was combined with other public data sources for the United States and all of its 366 metropolitan areas, which are statistical approximations of local and regional labor markets (e.g. a city and its suburbs). In the United States, Metropolitan Statistical Areas are defined by the U.S. Office of Management and Budget (OMB) based on data gathered by the Census Bureau. OMB locates these areas around a densely populated core, typically a city, of at least 50,000 people. Counties that have strong commuting ties to the core are then included in the definition of the metropolitan area.[53]

Focusing on the period from 1980 to 2010, the main measure of metropolitan economic performance used here is productivity, measured as value-added (or GDP) per worker. Unemployment rates were also analyzed as an outcome variable. In order to explain productivity and unemployment trends in metropolitan areas, a number of control variables were analyzed alongside patenting levels (the number of patents invented in a metropolitan area) and rates (patents invented per worker). These variables include population, the share of adults with a bachelor's degree or higher, the share of workers employed in the tech sector (see appendix for definition), housing prices, and the level of productivity predicted by a metro area's industrial mix and national averages of productivity in those sectors (i.e. predicted productivity). The motivation for using this variable is that it captures the effect of national productivity trends on metropolitan industrial sectors, and thus makes places like New York (with a large financial sector) comparable to Las Vegas (which has a large hospitality sector).[54]

The econometric analysis predicts the outcome variables using independent variables measured ten years in the past to avoid bias from reverse causation. The analysis also includes metropolitan effects, to control for unchanging characteristics of metropolitan areas, such as weather, history, and political institutions, and decade effects to capture national trends (in commodity or stock market prices, for example) that affect all metropolitan areas.

The appendix discusses more specific details of the data and analysis. Otherwise, the sources for information introduced into the text below are cited either directly or through endnotes. Much of the summary data here will be made available on the Brookings website at the report's homepage.

Findings

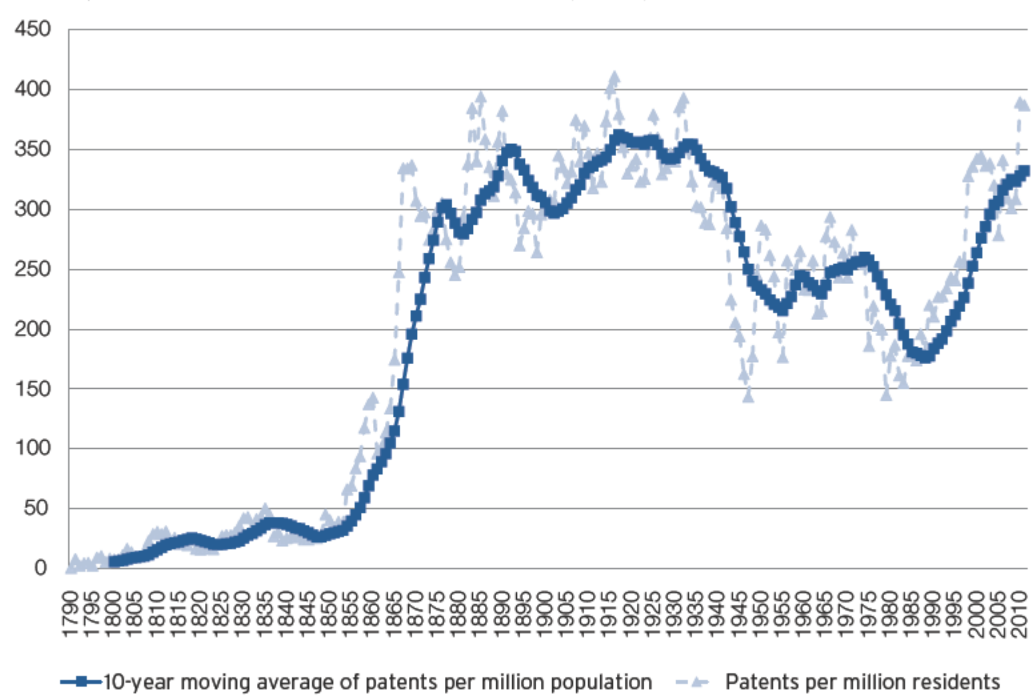
The rate of patenting in the United States has been increasing in recent decades and stands at historically high levels.

Though the United States was still recovering from the Great Recession, 2011 marked a new record high for the number of patents granted by the USPTO for both foreign and domestic-based inventors.[55]

As noted earlier, some economists and scholars have argued that invention is harder today than ever before because the "low-hanging fruit" has already been plucked. Yet, even if this is true, there are more scientists working today than ever before and research and development (R&D) spending is at an all time high. Science professors, engineers, and scientists comprised less than 1 out of every 1000 U.S. workers in 1910, but 25 out of every 1000 in 2010.[56] Perhaps, that is why the rate of patenting is nearly as high today as any point in U.S. history, as Figure 1 demonstrates covering 212 years of invention.

To be more exact, consider the 10 most inventive years in U.S. history, measured by patents per capita. The data excludes patents granted to foreign inventors. They are 1916, 1915, 1885, 1932, 2010, 2011, 1931, 1883, 1890, and 1917. In other words, two of these years came just after the Great Recession. The others were in the midst of the Industrial Revolution and post-Civil War America.

Figure 1. History of Patented U.S. Inventions per Capita, 1790–2011 by Year Granted



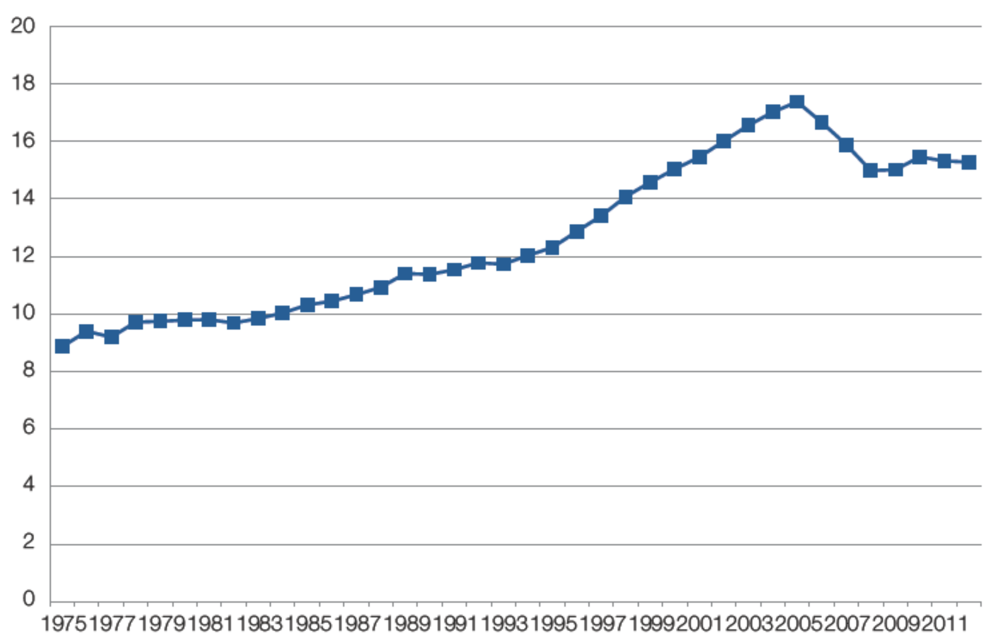
Stepping back, one can pick out a few eras of U.S. inventiveness. From 1790 to 1853, the rate of invention was very low, but it exploded in the Industrial Revolution starting in the mid-19th Century and lasting all the way until the Great Depression. Scholars have characterized this period of U.S. history as the "golden age" of invention when industries such as textiles, garments, household utensils, and farming implements experienced tremendous innovation.[57] With the onset of the Great Depression, the rate of invention plummeted from the 1930s to 1955, but there was a noticeable post-war rebound from 1956 to 1973, when the major research breakthroughs in modern information technology were first made. The decade from 1974 to 1984 saw a precipitous decline in inventive activity, but since, then, and starting in 1985, a post-industrial era of invention has begun and patent rates have steadily increased and remained high.

There was one exceptional period with respect to this current trend towards higher patenting rates. The years from 2002 to 2005 saw one of the largest four-year drops in patent per capita since the Civil War—a decline of 17 percent, compared to a 2 percent increase for the average four year period since 1870. This was the height of the investment bubble in subprime mortgages, but this drop off also reflects slowed application growth from 2001 to 2002 in the wake of the IT-bubble. Still, patent growth has been very strong since the Great Recession officially ended in 2009. The data in Figure 1 refer to granted patents by the year they were granted, which has been 3 to 4 years after its application in recently, but the trend is similar for applications; patent application growth was zero from 2007 to 2009 but accelerated to 7 percent from 2009 to 2010 and 3 percent from 2010 to 2011. One would, therefore, expect a spike in grants in 2013.

Scholars have noted the strong growth in patenting over the last two decades. Some have argued that it is the result of changes in patent law, particularly changes that allowed for software patents, or a relaxation of standards. In other words: Has quantity been achieved at the expense of quality?

There is evidence here to suggest otherwise. As others have found, objective measures of patent quality have been increasing in recent decades, such as the number of claims per patent.[58] The trend is illustrated in Figure 2. The number of claims per patent has increased steadily since 1975 and reached a high point in 2005 at 17.4. The measure declined during 2006 and 2007 and started

Figure 2. Trend in Claims and Citations (Within Eight Years of Grant) for all USPTO Patents Granted Between 1975 and 2012, by Year Granted



growing again in 2010. No recent decade has seen as many claims per patent as the 2000s. The slight dip in claims in recent years could be due to increases in the fees charged by the USPTO for over 20 claims.[59] Other scholars have found that the upward trend in claims is partly attributable to the internationalization of patent applications and the growing complexity of patenting, but much of the time trend cannot readily be explained.[60]

The increase in measured patent quality and patent rates coincides with an increase in R&D spending and does not appear to be entirely driven by legal changes, as patent scholars have noted.[61] Indeed, R&D expenditures, adjusted for inflation, increased by an annualized rate of 3.6 percent each year from 1980 to 2009, with roughly 70 percent coming from industry sources, and R&D spending since 1953 is highly correlated with patenting and the patent rate.[62] In 2008, inflation-adjusted R&D reached a record high, with 2009 as the last available year of data.[63]

If measured as a share of GDP, R&D spending has been more steady over the decades, but in 2009, the ratio—2.9 percent—equaled the historic high last achieved in 1964. R&D classified as basic, rather than applied or developmental, has increased the most rapidly since 1953.[64] The U.S. trend is less impressive, however, when compared to some other developed countries, when compared data is examined. From1981 to 2008, U.S. R&D growth was slower than a number of highly developed countries such as each of the Scandinavian countries, Spain, Australia, Canada, and Japan, though higher than many larger economies like Germany, the United Kingdom and France.[65]

The only modest relative growth in U.S. R&D may explain why, as noted in the introduction, the United States ranks just ninth in patents per capita, using appropriate international data. Patent scholars have noted a "home-office bias," meaning that European inventors tend to rely disproportionately on the EPO, Japanese inventors on the JPO, and US inventors on the USPTO.[66] The Organization for Economic Cooperation and Development (OECD), however, provides data on applications filed under the Patent Cooperation Treaty (PCT), which creates a universal application for patents that can be used across the major patent offices.[67] Such patents tend to be more valuable than those using only the domestic office applications.[68] This limits the comparison to potentially international patents. On this score the United States ranks ninth on patent applications filed under the PCT system from 2000 to 2010, below (in order from the highest) Sweden, Finland, Switzerland, Israel, the Netherlands, Denmark, Germany, and Japan. Using only 2010 data, the United States falls to 12th, as Korea, Norway, and Austria move ahead. The average Swede is roughly twice as likely to file a PCT application as the average American. Those U.S. rankings are identical using data on patents granted by the USPTO and filed at all three major offices (EPO, JPO, and USPTO).[69]

The inventions from these countries, on net, will likely benefit U.S. consumers, even as some companies and workers lose out from competition, but what is more troubling is that additional R&D spending has not translated into as many patents as one might have expected. Consistent with the concern that technologies are becoming more complex, fewer inventions are patented for every dollar of R&D. From 1953 to 1974, one patent was generated for every $1.8 million of R&D. Since 1975, the average implicit "cost" has been $3.5 million, about twice as high, in inflation adjusted dollars. As other scholars have found, the increased cost of R&D per patent could be at least partly attributed to an increase in quality, but it means R&D growth must accelerate.[70]

The trend in R&D and claims suggest that the increase in the patenting rate may reflect a real increase in the number of valuable inventions. Skeptical readers, however, may still want further evidence that the trend is not the result of relaxed approval standards, a surge in foreign-inventor contributions, or the perverse incentives of litigation. While these and other explanations cannot be definitely rejected, the broad evidence is consistent with the conclusion that the rate of invention is increasing along with the rate of patenting. The share of patents that have received no citations—which does not necessarily indicate that they are or poor quality—has held steady between five and six percent in the 1980s and 1990s.[71] Moreover, while the share of USPTO patented granted to foreign inventors has increased dramatically (and is now almost half), those granted to domestic inventors make significantly more intellectual property claims and receive more subsequent citations by a wide margin, as Table 1 displays.

It is also unlikely that changes in litigation practice explain the increased patenting rate. Annualized growth in re-examinations from 1981 to 2011 was 4.9 percent compared to 4.8 percent patent growth.[72] Median damages amounted to $2 million in 2010, according to one study, but there was no upward

Table 1. Intellectual Property Claims and Citations Within Eight Years of Grant by Foreign Status of Inventor, for All Granted Patents Applied For, 1975–2012

	Claims	Citations within 8 years
U.S. Inventors	15.1	8.0
Foreign Inventors	12.1	5.1

Source: Brookings analysis of Strumsky patent database

Table 2. Claims per Patent, and Eight-Year Citations per Patent, in the 10 Largest Subcategories

Subcategory	Annual Granted Patents, applications from 2006-2010	Claims per patent, applied for from 2006-2010	Citations per patent, applied for from 1991-1995
Communications	10,711	17.2	16.0
Computer Software	8,395	17.5	18.9
Semiconductor Devices	8,258	14.2	14.1
Computer Hardware & Peripherals	7,327	16.1	16.2
Power Systems	6,904	11.7	9.4
Electrical Systems & Devices	5,540	13.8	8.0
Biotechnology	5,189	15.3	7.0
Measuring & Testing	4,652	13.5	7.2
Information Storage	4,626	15.6	11.8
Transportation	4,533	9.0	6.6
10 largest subcategories	**66,134**	**14.4**	**11.5**
All subcategories	**138,312**	**12.8**	**9.8**

Source: Brookings analysis of Strumsky patent database. Patents years are determined by year of application. Each period observation is the average of the five year period ending that year. The subtotal and total rows display totals in the first column and un-weighted averages in the second and third columns.

trend compared to recent years.[73] While litigation has been increasing, the rate of growth is consistent with the rate of growth in patenting. The number of patent cases filed at U.S. District Courts as a percentage of all patents remained stable from 1970 to 2008.[74] The rate has hovered between 1.2 and 1.6 percent of patents granted.[75] By historic standards, this is actually not particularly high, though comparisons across different institutional arrangements and eras are subject to considerable error. In the early years of the industrial revolution, the rate was as high as 3.6 percent in the 1840s and 2.1 in the 1850s; many disputes concerned manufacturing industry inventions, the tech sector of the 19th century.[76] Before Bell Labs established itself as the darling of invention, Alexander Graham Bell won large patent infringement cases in the 1870s.[77] Likewise, industrial giants GE, founded by Thomas Edison, and Westinghouse filed hundreds of patent suits in the 1890s.[78] None of this is to suggest that the threat of law suits or the trend in undisclosed settlements have not increased or that of the patent system's rules are optimal.[79]

To better understand patenting trends, one can start by looking at which technologies are represented in patents. First of all, almost half (46 percent) of all patents can be grouped in the 10 largest categories; the patents in this group tend to make more claims and receive more citations compared to smaller technological groups, which may or may not reflect underlying value.

The most prominent technological category is communications. Over the five year period ending in 2010, 10,000 patents were granted to communications technologies, and as Table 2 shows, these patents were also highly valuable in terms of claims and citations. Leading patent owners over the five year period include Cisco, IBM, AT&T, Qualcomm. Two of the next four categories are directly linked to computers—software (e.g. Microsoft) and hardware (e.g. Apple), and also score highly on citations and

Table 3. Subcategories with the Fastest and Slowest Growth Rates in Patenting from 1980 To 2005, by Change in Value Measures

Subcategory	Annual Growth Rate in Patents, 1980-2005 (moving average)	Change in Claims per Patent, 1980 to 2005	Change in Eight- year Citations per Patent, 1980 to 1995
Subcategories with the fastest growth in patents			
Computer Software	11%	7.3	12.1
Data Processing	11%	6.3	11.0
Semiconductor Devices	10%	6.0	8.1
Video Distribution Systems	10%	7.0	36.1
Computer Hardware & Peripherals	8%	7.0	9.2
Chemical-Crystals	8%	5.4	7.6
Nanotechnology	8%	10.3	5.5
Information Storage	6%	7.3	6.8
Communications	6%	8.4	11.7
Design	5%	0.0	2.4
Subcategories with the slowest growth in patents			
Chemical-Purification/Evaporation/Distillation	-2%	6.0	3.6
Chemical-General Compound & Compositions	-3%	5.4	3.0
Time Measurement & Horology	-3%	5.1	3.1
Machine Element or Mechanism	-3%	5.7	2.9
Chemical-Manufacture Specific	-3%	7.5	3.9
Organic Compounds	-3%	5.0	2.5
Pipes & Joints	-3%	5.2	3.1
Education & Demonstration	-4%	7.4	10.9
Hazardous Waste	-4%	5.7	0.5
Heating, Refrigeration & Ventilation	-4%	6.8	2.8

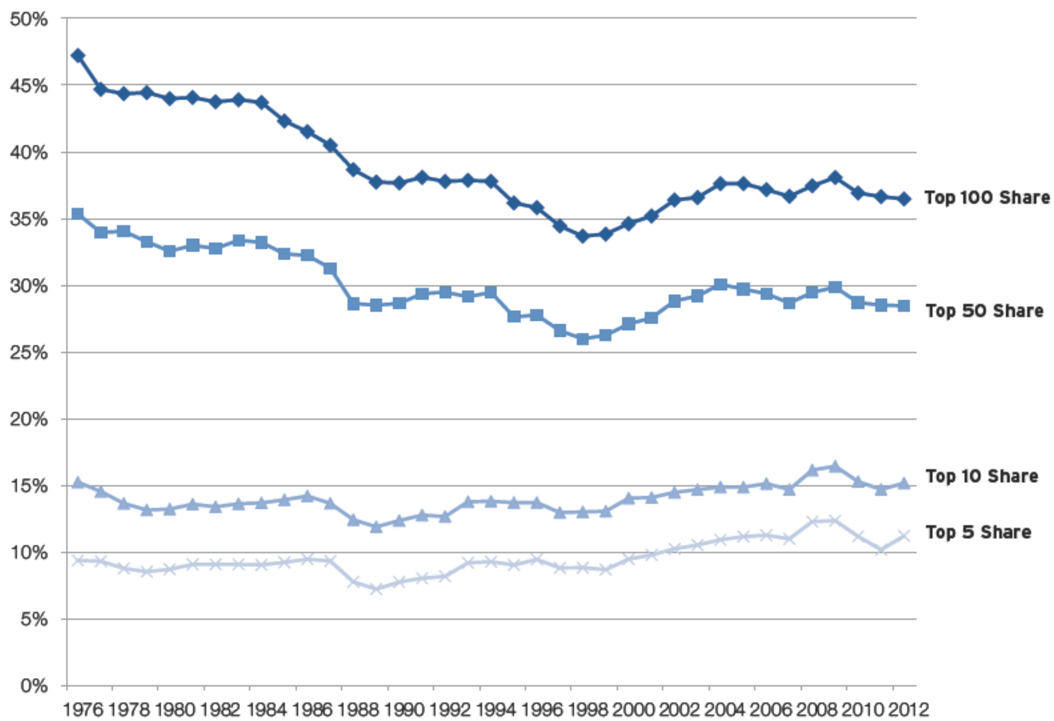
Source: Brookings analysis of Strumsky patent database. Patents years are determined by year of application. Each period observation is the average of the five year period ending that year.

claims. In general, the computer and information technology patents tend to make the most claims and receive the most citations; the large number of citations may reflect the large scale of the industry's patenting activities, which would require documenting previous work.

Other large technological groups tend to receive fewer citations and make fewer claims, but nonetheless make large contributions to U.S. and global invention, including a number of older industrial categories related to power, electrical systems, measuring devices, and transportation. For Electrical Systems and Devices, some of the leading owners of patents granted between 2006 and 2010 were IBM, Tyco Electronics (now TE Connectivity), Intel, Broadcom, Texas Instruments, Micron, and the Eaton Corporation. Transportation includes the auto and aerospace industries, with prominent patent owners including Goodyear, Ford, GM, Boeing, Honda, Delphi, Lockheed Martin, and Caterpillar. Large inventors of Power Systems patents include GE, IBM, GM, HP, Lutron Electronics, and Honeywell. Leading Measuring and Testing patent owners include some lesser known companies like KLA-Tencor, Schlumberger, Agilent, Applied Materials, and Zygo.

Table 3 reports the technological categories with the strongest and weakest growth rates in patenting from the five year period ending in 1980 to the five year period ending in 2005. Again information and communication technologies are among the strongest growing technological categories, led by Computer Software, Data Processing, Video Distribution Systems, Computer Hardware, Information Storage, and Communications. Computer and information related technologies have also seen sharp increases in claims and citations per patent. The Nanotechnology category is not frequently used by the patent examiners, considering that it has less than 1000 total patents, but it has been growing rapidly in recent years. It refers mostly to microscopic measurement devices. The Design category refers

Figure 3. Share of Patents Held by Largest 5, 10, 50, and 100 Patent Owners by Year of Grant, 1976-2012



to the design aspects of miscellaneous machines and cosmetic products, with leading patent owners including Black and Decker, Procter and Gamble, and Gillette.

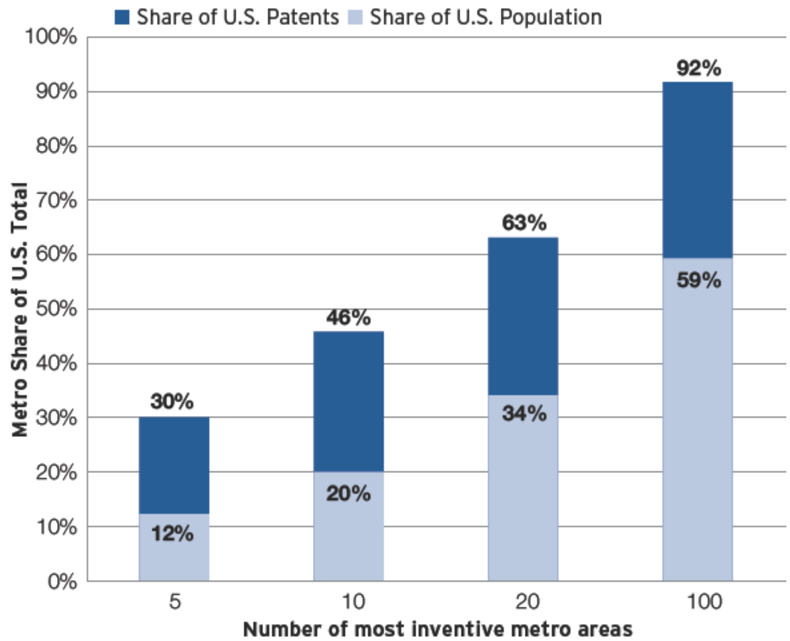
One implication of the industry category analysis becomes clear: Most patents, especially of higher value, are being generated by a small number of industries, disproportionately and primarily in fields like computer and information technology, electronics, biotechnology, energy, and transportation. As a recent report from the USPTO documented, patent intensive industries employ just a small fraction of the U.S. workforce, and yet these industries drive most of the technological changes that increase living standards, by reducing the costs of things like food, energy, and information.[80]

Yet, that industry concentration has not coincided with limited competition. As Figure 4 shows, patent ownership has become more dispersed since the mid 1970s and 1980s, at least outside the very largest firms. The share of patents held by the top 5 patent owning companies has increased slightly from 9 percent in 1976 to 11 percent in 2012, but the top 10 share has remained stable, and the top 50 and top 100 shares have fallen by 7 and 11 percentage points respectively. The trend is similar even in the more concentrated and controversial category of software patents.

Even these data understate the creative destruction of high-tech companies for the list of companies at the top has changed. In recent years (2011 and 2012), just 4 of the top 10 owners of patents granted those years were in the top 10 between 1976 and 1980: IBM, GE, GM, and AT&T (counting Bell Labs as the antecedent). Of the rest, Hewlett-Packard cracked the top 10 for the first time in 1992, Microsoft and Intel in 1996, Cisco in 2006, Broadcom in 2009, and Apple not until 2010. In other words, even while a few tech giants account for a large share of the nation's patents, patent ownership as a whole has become broader and more competitive with considerable churn both at the top and throughout the distribution, including a massive increase in the number of firms with just one patent per year. In 1976, 2,677 companies or organizations (like universities or federal agencies) owned exactly one patent granted that year; by 2011, that number had soared to 9,909.

From 1980 to 2011, the average metropolitan area saw a 7 percentage point drop in the share of newly granted patents held by the largest patent owner and a 2 percentage point drop in the share

Figure 4. Concentration of U.S. Patents Invented in Most Inventive Metro Areas from 2000-2012 Relative to 2010 Population Shares



held by the top 5 assignees. Many high patenting metropolitan areas saw patents disperse widely across firms. In Indianapolis, for example, there was a 29 percentage point decrease from 1980 to 2011 in the share of patents owned by the top 5; in Boulder, Colorado there was a 27 percentage point decrease; a 17 percentage point decrease in Austin, and an 8 percentage point decline for San Francisco. In general, the more patents in a region, the wider the dispersion across firms at any given time.

To summarize this section, patent data implies that the rate of invention—at least of patentable inventions—is near historic highs, quality appears to be increasing and not as the result of changes in litigation practices, a few industries are responsible for most patenting activity, and competition between patent owners seems to have increased.

Still, give the geographic concentration of industries and production, the gains from patenting may be similarly concentrated and of little benefit to large numbers of Americans. For all the dispersal of invention, relative to the hierarchical corporate labs of the 1970s, there remains a massively unequal distribution of patents across metropolitan areas. The next sections turn to the spatial geography of patenting and its effect on economic performance.

Most U.S. patents—63 percent—are developed by people living in just 20 metro areas, which are home to 34 percent of the U.S. population

Metropolitan areas play a critical role in setting the productivity of the U.S. economy.[81] Large metros in particular account for a disproportionate share of GDP and educated workers, but they are especially crucial for patenting. The 100 largest metro areas are home to 65 percent of the U.S population in 2010, but they are home to for 80 percent of all U.S. inventors of granted patents since 1976 and 82 percent since 2005. Few patents are invented outside of metro areas. In fact, 93 percent of all U.S. patent inventors have lived in metro areas since 1976 (using the year of application).

U.S. patented invention is highly concentrated in a relatively small number of cities and their suburbs, as Figure 1 reinforces. Indeed, just the five most patent intensive metro areas accounted for 30 percent of all patents from U.S. inventors. The average resident in these five metro areas is 2.4 times

Table 4. Total Granted Patents and Patenting Rate by Metropolitan Area of Inventor, 2007–2011

	Average Granted Patents per year, 2007-2011	Patents per million residents, 2007-2011	Largest subcategory of patents
San Jose-Sunnyvale-Santa Clara, CA	9,237	5,066	Computer Hardware & Peripherals
San Francisco-Oakland-Fremont, CA	7,003	1,638	Biotechnology
New York-Northern New Jersey-Long Island, NY-NJ-PA	6,907	366	Communications
Los Angeles-Long Beach-Santa Ana, CA	5,456	424	Communications
Seattle-Tacoma-Bellevue, WA	3,968	1,174	Computer Software
Boston-Cambridge-Quincy, MA-NH	3,965	877	Biotechnology
Chicago-Joliet-Naperville, IL-IN-WI	3,886	409	Communications
San Diego-Carlsbad-San Marcos, CA	3,165	1,041	Communications
Minneapolis-St. Paul-Bloomington, MN-WI	3,068	945	Surgery & Medical Instruments
Detroit-Warren-Livonia, MI	2,720	621	Transportation
Austin-Round Rock-San Marcos, TX	2,497	1,503	Computer Hardware & Peripherals
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	2,370	402	Biotechnology
Houston-Sugar Land-Baytown, TX	2,202	379	Earth Working & Wells
Dallas-Fort Worth-Arlington, TX	1,945	310	Communications
Portland-Vancouver-Hillsboro, OR-WA	1,844	837	Computer Hardware & Peripherals
Atlanta-Sandy Springs-Marietta, GA	1,506	285	Communications
Washington-Arlington-Alexandria, DC-VA-MD-WV	1,479	271	Communications
Phoenix-Mesa-Glendale, AZ	1,437	343	Semiconductor Devices
Raleigh-Cary, NC	1,273	1,164	Computer Hardware & Peripherals
Poughkeepsie-Newburgh-Middletown, NY	1,226	1,829	Semiconductor Devices
Average of all metropolitan areas	299	296	

Source: Brookings analysis of Strumsky Patent Database and American Community Survey. One patent is assigned to a metro area if at least one inventor lives there. Year refers to year of application, not grant. Since it takes a few years for an application to become granted, these patent totals are artificially low.

more likely to invent a patent than the average American. The 10 most inventive metro areas account for nearly half of all patents, 46 percent, and the 100 most inventive metros account for 92 percent. These metro areas contain a hugely disproportionate number of highly specialized researchers, engineers, and entrepreneurs who are coming up with new technologies.

This degree of concentration has not changed much since the 1980s, though two trends are worth noting. The concentration of patents in the 100 most inventive metro areas has increased from 90 in the 1980s to 92 (since 2000), even as the share concentrated in the top five fell from 32 to 30. In other words, invention is slightly more concentrated in large metro areas than it was three decades ago, but the dominant regions have lost market share to other highly inventive areas.

From 1980 to 2011, a few large metros notably changed their share of U.S patents.[82] At the top, San Jose moved up from ninth to first, and San Francisco moved from seventh to fourth, moving ahead of Chicago, Philadelphia, Detroit, and Boston. Seattle and San Diego moved up 15 and nine places, respectively, to become seventh and eighth. Meanwhile, Austin and Raleigh moved up 41 and 55 places, respectively, to become 11th and 20th. Cleveland fell 10 slots from 13th to 23rd, while Philadelphia fell from fourth to 13th.

Although the high-patenting metro areas are all large, patenting per capita rates (a measure of the inventive productivity of an area) vary widely. Table 4 lists the metro areas of any size with the highest number of granted patent over the five year period ending in 2011. In the last column, the largest patenting subcategory is listed for each metro to provide a sense of the most prominent patenting industries.

With computer hardware and peripherals as the lead category, San Jose stands out with 9,237 patents per year, from 2007 to 2011. This is 2000 more patents than the next highest metro area—its neighbor, San Francisco. Of the other large metros on the list, New York, Chicago, Washington D.C.,

Table 5. Total Granted Patents and Patenting Rate by Metropolitan Area of Inventor, 2007–2011

	Patents per million residents, 2007-2011	Average Granted Patents per year, 2007-2011	Largest subcategory of patents
San Jose-Sunnyvale-Santa Clara, CA	5,066	9,237	Computer Hardware & Peripherals
Burlington-South Burlington, VT	3,951	826	Semiconductor Devices
Rochester, MN	3,300	606	Computer Hardware & Peripherals
Corvallis, OR	2,319	194	Semiconductor Devices
Boulder, CO	2,274	666	Communications
Poughkeepsie-Newburgh-Middletown, NY	1,829	1,226	Semiconductor Devices
Ann Arbor, MI	1,697	590	Motors, Engines & Parts
San Francisco-Oakland-Fremont, CA	1,638	7,003	Biotechnology
Austin-Round Rock-San Marcos, TX	1,503	2,497	Computer Hardware & Peripherals
Santa Cruz-Watsonville, CA	1,204	310	Computer Hardware & Peripherals
Seattle-Tacoma-Bellevue, WA	1,174	3,968	Computer Software
Raleigh-Cary, NC	1,164	1,273	Computer Hardware & Peripherals
Rochester, NY	1,149	1,198	Optics
Durham-Chapel Hill, NC	1,120	552	Biotechnology
Trenton-Ewing, NJ	1,073	393	Biotechnology
Sheboygan, WI	1,045	120	Invalid USPTO Code
San Diego-Carlsbad-San Marcos, CA	1,041	3,165	Communications
Albany-Schenectady-Troy, NY	981	846	Power Systems
Ithaca, NY	959	97	Biotechnology
Minneapolis-St. Paul-Bloomington, MN-WI	945	3,068	Surgery & Medical Instruments

Source: Brookings analysis of Strumsky Patent Database and American Community Survey. One patent is assigned to a metro area if at least one inventor lives there. Year refers to year of application, not grant.

Miami, and Atlanta have rather low patenting rates—less than 10 times the rate of invention in San Jose. On the other hand, San Francisco, Boston, Austin, Seattle, San Diego, Portland, Rochester, and Minneapolis are in an upper tier of large metros that produce patents at high volumes and rates.

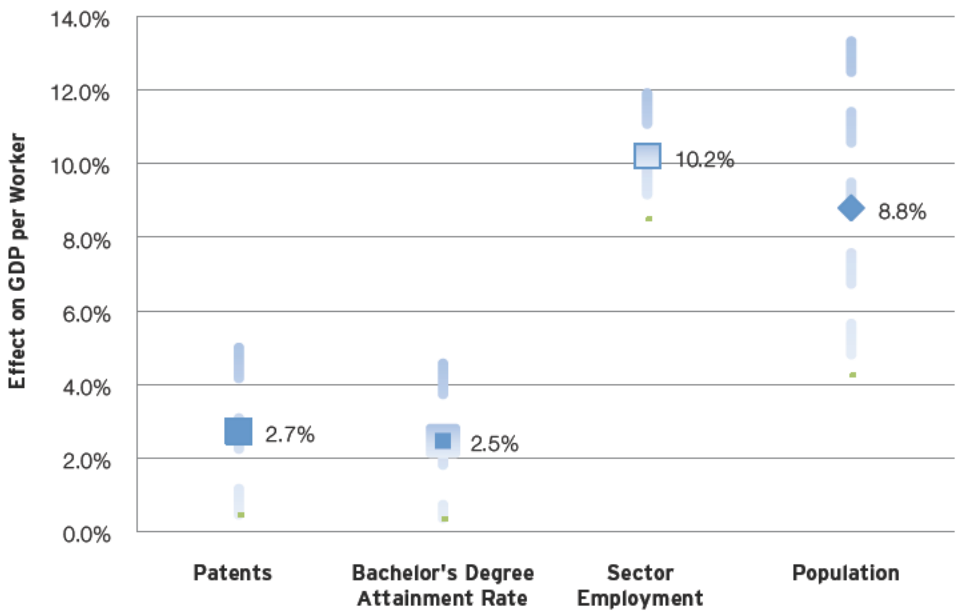
Many of the metro areas just mentioned also develop patents at extraordinarily high rates, especially San Jose; with over 5,000 patents per million residents in any given year from 2007 to 2011 it is the most inventive metro area by size and intensity. As Table 5 shows, highly inventive metro areas are scattered across each region of the country. In the Northeast there is Burlington, Vermont, one in New Jersey (Trenton in Mercer County, which includes Princeton), and three more in New York. The West is represented by 7 of the top 20 metro areas, including 4 in California, as well as Corvallis, Oregon, Seattle, and Boulder Colorado. The Midwest has four—with Rochester, Minnesota rating the highest—and the south three, with Austin, Texas and two in North Carolina.

The differences in patenting rates are truly large, when metro areas at the extremes are placed side by side. A resident living in one of the 100 most inventive metropolitan areas is seven times more likely to invent a patent than someone living in lower ranked metropolitan area. A resident of the San Jose metropolitan area is 600 times more likely to invent a patent than a resident of McAllen, Texas, 160 times more likely than a resident of Johnstown, Pennsylvania, and 100 times more likely than residents of Fresno, California or Lakeland-Winter Haven, Florida. Even compared to a high-patenting area like metropolitan Detroit, a San Jose resident is 8 times more likely to invent.

Inventions, embodied in patents, are a major driver of long-term regional economic performance, especially if the patents are of higher quality.

It is well documented that inventors and companies do not benefit from the full value of their products.[83] Much goes to consumers or society, in form of better health and higher quality, more affordable goods and services. Regions too are unlikely to capture the full benefits of ideas invented there that

Figure 5. Average 10-Year Marginal Effect of Metro Area Patents and Other Variables on Total Metro Area Productivity Growth, with 95 Percent Confidence Intervals, 1980-2010



eventually become commercialized, traded, implemented, and perhaps even copied. With this in mind, the question arises: Do regions benefit from having many inventors?

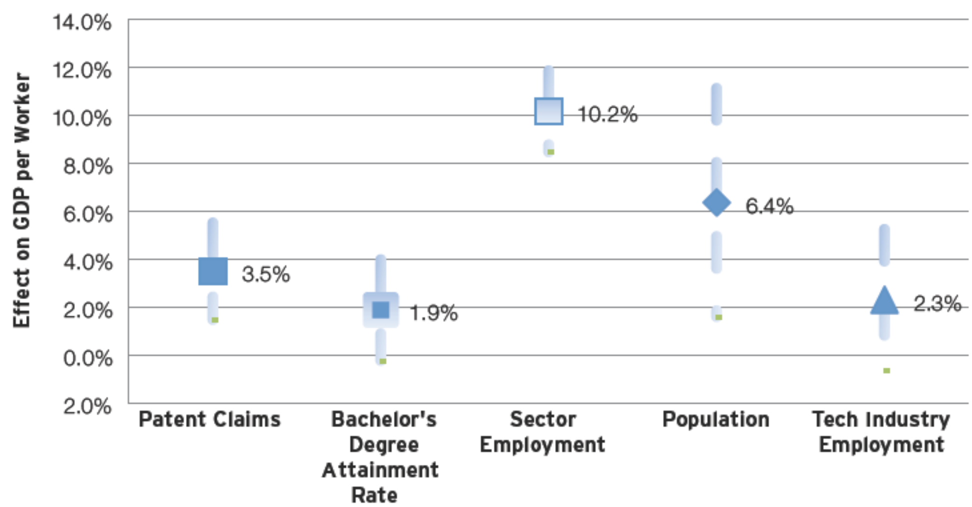
To answer this question, regression analysis was used to assess the relationship between patents and productivity growth—measured as GDP per worker—from 1980 to 2010 for every metropolitan area in the United States (with available data that came to 358). Since many other factors affect productivity but might be correlated with patenting, the analysis controls for the share of college graduates living in the metro area, population size, industry concentration, housing prices, and constant metropolitan specific characteristics (which would include geographic advantages, history, and political institutions). The econometric details are shown in the appendix

The results clearly show that patenting is associated with higher metropolitan area productivity. The analysis cannot rule out that the link is caused by some missing variable or reverse causality, but given the control variables and the fact that patents were lagged ten years in the analysis, the most likely explanation is that patents cause growth. In order to translate the evidence into concrete terms, one can group metropolitan areas into quartiles of patenting, with the most inventive metros (by number of patents) in the top quartile.

If the metro areas in the lowest quartile, patented as much as those in the top quartile, they would boost their economic growth by 6.5 percent over a ten year period. By comparison, the average metro area in this bottom quartile grew by 13 percent each decade over this period, so an extra 6.5 percent would be a large boost, representing an extra $4,300 per worker (adjusted for inflation). That would require, roughly, an extra 960 patents per year. Though not without difficulty, such figures could be generated by a few large corporate R&D offices or universities.

The other notable finding is that patents compare rather well to other growth-enhancing factors, like human capital. First of all, five variables analyzed in this analysis are all statistically significant and economically meaningful. With that said, the patenting effect is somewhat larger than the effect from bachelor's degree attainment. A one standard deviation of growth in the number of patents (or, more precisely, the natural log of patents) granted to metro area inventors is associated with a 2.7 percent increase in economic growth—measured as output per worker. That compares to 2.5 percent for a one

Figure 6. Average 10-Year Marginal Effect of Metro Area Claims and Other Variables on Total Metro Area Productivity Growth, with 95 Percent Confidence Intervals, 1980-2010



standard deviation increase in the bachelor's degree attainment rate and slightly less for the sector employment effect.

The patenting effect is important, but it is smaller than the effects from population size and sector employment concentrations. The sector effect is the largest. The interpretation is intuitive: Where employment is concentrated in high-productivity industries (e.g. energy, utilities, finance, information, and professional services), metropolitan area output per worker is consistently higher. Where it is in low-productivity sectors---like health care, leisure and hospitality (tourism), education, restaurants, and agriculture—metro area productivity is low.

Population also has a large effect on productivity. This is the well documented phenomena that firms are more productive when they exist in clusters of related businesses and in large urban areas.[84]

Patenting Quality

Patent claims have a larger effect on metropolitan productivity than patents themselves. This makes sense if one considers that a patent with many claims is akin to multiple patents with few claims. In fact, after accounting for the number of claims, patents do not add value to a metropolitan economy.

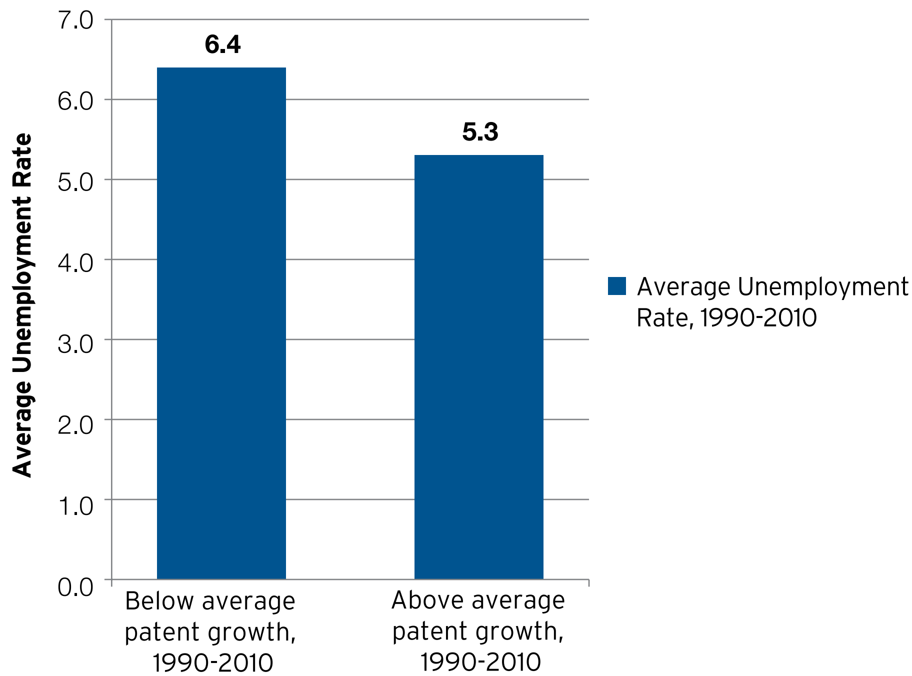
To test the strength of these conclusions, the analysis also considered the effects of employment in tech industries, which are high-patent industries. The motivation for this is that tech sector workers and their companies may have other characteristics—besides high patenting rates—that are associated with productivity (e.g. higher education levels, export orientation, and wages).[85]

The effects of patent claims are compared to other variables, as was done above with patents, in Figure 7, shown above. Patent claims are highly significant and strongly associated with productivity growth. Industrial sector and population effects are larger, though the effects of population and patent claims overlap, so one cannot be sure that they differ. Meanwhile, bachelor's degree attainment is now marginally insignificant, as is tech-sector employment. They are highly correlated, and further analysis shows that their combined effect is highly significant.[86]

Metropolitan Level Trends in Productivity

The aggregate results reported above become more concrete when looking at specific metropolitan areas. Table 6 lists the large metropolitan areas with the largest increase in patents per worker from 1980 to 2010, along with their performance on productivity growth, the change in the bachelor degree

Figure 7. Average Unemployment Rates of Metropolitan Areas with Above and Below Average Growth in Patents from 1990 to 2010



attainment rate, and growth in predicted productivity (based on how national trends in sector productivity would be expected to affect metro areas, given their sector mix).

San Jose, again, tops the list, with an increase of 13,206 patents per million workers from the 1980 to 2010. Stated otherwise, the probability that a given worker in San Jose invented a patent increased by 1.3 percentage points—and the increase will be even higher as pending patents become granted in the next few years. As it happens, San Jose also experienced the highest productivity growth, and much of that growth cannot be explained by its re-orientation towards more productive economic sectors, as a comparison between the second and the third columns suggests.

Patenting is correlated with productivity growth: 14 of the 20 metro areas with the largest increase in patents per worker from 1980 to 2010 (out of the 358 with complete data) experienced above average productivity growth. Indeed, in addition to San Jose, four of those other metro areas are also ranked in the top 20 on productivity growth: Corvallis, OR; Boulder, CO; Raleigh, NC; and Portland, OR. In each case, sector re-orientation towards higher-productivity industries would predict lower growth rates than they actually experienced, suggesting that other factors were at work. In addition to explosive patent growth, Raleigh and Boulder had rapid increases in human capital, measured by the share of adults aged 25 and older with a bachelor's degree or higher, but this was not the case in Corvallis and Portland, where the increase in bachelor degree attainment shares was below average.

For the six metro areas with a large patent increase but low productivity growth, five of them shifted employment towards low productivity but stable economic sectors like education and health care (e.g. in Provo, home to BYU, 22 percent of workers were employed in education and health care, compared to 14 percentage nationally). The other—Racine, Wisconsin—suffered from stagnant population growth and a meager increase in the bachelor's degree attainment rate.

The same relationship between patents and productivity changes can be drawn by examining metropolitan areas with that developed fewer patents per worker over the three decades. Rust belt metro areas with low productivity growth—like Pittsburgh, Toledo, and Buffalo—actually saw a decrease in the number of patents per worker. This is also true of Tulsa, Oklahoma, Louisville, and Baton Rouge, all

Table 6. Productivity Growth in the 20 Metropolitan Areas with the Largest Increase in Patents per Worker, 1980-2010

	Change in patents per million workers, 1980-2010	Annual Productivity Growth, 1980-2010	Predicted Productivity Growth, 1980-2010	Change in Bachelors Degree Attainment 1980-2010
San Jose-Sunnyvale-Santa Clara, CA	13,206	3.3%	2.2%	18.4%
Burlington-South Burlington, VT	8,355	2.1%	1.7%	16.6%
Corvallis, OR	6,644	2.6%	1.1%	11.3%
Winchester, VA-WV	6,633	1.6%	1.6%	10.5%
Rochester, MN	6,536	1.6%	0.9%	14.0%
Charlottesville, VA	4,491	1.4%	1.4%	15.1%
Poughkeepsie-Newburgh-Middletown, NY	4,219	1.8%	1.4%	12.7%
San Francisco-Oakland-Fremont, CA	4,059	1.9%	1.2%	17.5%
Blacksburg-Christiansburg-Radford, VA	3,709	1.3%	1.2%	11.5%
Austin-Round Rock-San Marcos, TX	3,591	1.9%	1.3%	12.8%
Santa Cruz-Watsonville, CA	3,547	1.7%	1.1%	13.7%
Boulder, CO	3,182	2.3%	1.8%	20.6%
Seattle-Tacoma-Bellevue, WA	2,957	1.3%	1.5%	14.8%
Raleigh-Cary, NC	2,848	2.3%	1.9%	19.8%
Ann Arbor, MI	2,602	1.1%	1.5%	14.7%
San Diego-Carlsbad-San Marcos, CA	2,357	2.2%	1.3%	13.1%
Durham-Chapel Hill, NC	2,212	1.9%	1.5%	17.8%
Provo-Orem, UT	2,062	0.5%	1.3%	12.0%
Portland-Vancouver-Hillsboro, OR-WA	2,056	2.5%	1.3%	13.9%
Racine, WI	2,046	1.0%	1.8%	9.0%
Average for top 20 metros	**4,366**	**1.8%**	**1.5%**	**14.5%**
Average of all metro areas	**395**	**1.4%**	**1.4%**	**9.7%**

Source: Brookings analysis of Strumsky database, U.S. Census Bureau, and Moody's Analytics. Patent totals for 1980 and 2010 are based on five year moving averages that end in those years, since patent data fluctuates from year to year. Figures are based on application year of patents already granted. Predicted industry productivity multiplies metro area employment shares by sector by national productivity for each sector. The growth rate is calculated using 1980 and 2010 measures.

three of which had very slow productivity growth.

On the other hand, a metropolitan area like Detroit does not fit the model in any simple way. It ranked 37th on the increase in patents per worker, but 306th in productivity growth, 185th on predicted productivity growth, 248th on tech sector job growth, and 316th on population growth. Here, the outsourcing of production to the U.S. South and other countries is likely a major factor. The case of Detroit serves as a warning that patenting alone will not guarantee prosperity; rather it must be combined with other pro-growth attributes that Detroit evidently has been lacking.

Invention and Unemployment in Metropolitan Areas

While granting that patents add value to a regional economy, some may be concerned about how technology-led productivity growth affects labor demand, since new technologies require few workers.[87] On the other hand, more productive metro areas have more money available to spend on local services, which should boost job creation.

This analysis finds that patent growth is strongly correlated with better employment opportunities. From 1990 to 2010, metro areas with faster growth in patenting had significantly lower average unemployment rates during those two decades. The analysis, which is summarized in Figure 8, was conducted using all metro areas and controlling for changes in college educational attainment rates, population growth, housing price growth, tech sector growth, and predicted industry growth. (The results are shown in more detail in Appendix Table 2). Focusing on just the 100 largest metro areas for ease of comparison, lists those with the highest and lowest patent growth rates.

Table 7. Average Unemployment Rates from 1990 to 2010 and Patent Growth in the 100 Largest Metro Areas

	Unemployment Rate, average 1990-2010	Patent Growth, annual average 1990-2010	Change in share of population with Bachelor's or higher, 1990-2010	Job growth, annual average 1990-2010
Metro Areas with the highest growth in patents from 1990 to 2010				
Boise City-Nampa, ID	4.6	11.90%	8.40%	2.90%
Provo-Orem, UT	4.1	8.90%	9.20%	2.90%
Seattle-Tacoma-Bellevue, WA	5.5	8.90%	10.00%	1.20%
Raleigh-Cary, NC	4	8.80%	11.40%	2.60%
San Jose-Sunnyvale-Santa Clara, CA	5.9	8.10%	12.40%	0.20%
Austin-Round Rock-San Marcos, TX	4.3	8.10%	8.70%	3.40%
Las Vegas-Paradise, NV	6	7.20%	7.90%	3.80%
San Francisco-Oakland-Fremont, CA	5.4	7.00%	11.50%	0.20%
Poughkeepsie-Newburgh-Middletown, NY	4.9	6.60%	7.70%	0.40%
Tucson, AZ	4.7	6.50%	6.30%	1.70%
Average for high growth metro areas	**4.9**	**8.20%**	**9.30%**	**1.90%**
Metro Areas with the lowest growth in patents from 1990 to 2010				
Lakeland-Winter Haven, FL	7.1	-1.10%	5.10%	1.10%
Pittsburgh, PA	5.6	-1.10%	10.10%	0.30%
Buffalo-Niagara Falls, NY	5.9	-1.20%	8.50%	-0.10%
Toledo, OH	6.8	-1.30%	6.10%	-0.20%
El Paso, TX	9.2	-1.40%	4.10%	1.40%
Dayton, OH	5.7	-1.60%	5.30%	-0.60%
Tulsa, OK	4.8	-1.70%	5.30%	1.10%
Chattanooga, TN-GA	5.1	-2.10%	6.90%	0.60%
New Orleans-Metairie-Kenner, LA	6.1	-2.50%	6.40%	-0.20%
Baton Rouge, LA	5.4	-5.30%	5.20%	1.60%
Average for low growth metro areas	**6.2**	**-1.90%**	**6.30%**	**0.50%**
Average for all large metro areas	**5.7**	**2.30%**	**7.90%**	**1.00%**

Source: Brookings analysis of Moody's Analytic, Bureau of Labor Statistics, Census Bureau Decennial Census, and Strumsky Patent Database. One patent is assigned to metro area if at least one inventor lives there.

Metro areas with the fastest growth in patenting tend to have lower unemployment during the period. Boise, Provo, Raleigh, Austin, Poughkeepsie, and Tucson all had high patenting growth and average unemployment rates below five percent; the average for the ten fastest growing metro areas was 4.9 percent. By contrast, large metros with slow patenting growth had an average unemployment rate of 6.2 percent. Places like Buffalo and Dayton represent once strong manufacturing hubs that lost their inventive momentum.

Patenting growth is also correlated with job growth, population growth, and increases in educational attainment rates. Yet, closer analysis reveals that education is more important to metro area job growth than patenting, which becomes insignificant. One explanation is that patenting growth only leads to job growth if it draws highly educated workers to the metropolitan area.

Overall, the evidence here is that patenting is good for metro area labor markets. The higher productivity does not seem to come at the expense of workers. Long-run unemployment rates are lower in metro areas with faster patent growth, meaning that opportunities for workers are more prevalent. Net job creation also tends to be higher in metros with higher patenting growth, but this effect is the result of growth in educational attainment.

Invention and the Creation of Public Companies

During the painfully slow recovery from the Great Recession, many have wondered whether America's entrepreneurial vigor has been sapped.[88] If patents are associated with the creation of new products and economic value, they may also help create new companies. That is, in fact, what the data suggest.

The effect of patenting on high-technology start-ups can be gleaned by examining the value of Initial Public Offerings (IPOs) occurring in metropolitan areas which have high patenting intensity. IPOs have come to be associated with high-technology start-ups, and are used by companies to raise money for expansion and monetize earlier investments.[89] A new database by innovation scholars has identified every tech-sector IPO from 1996 to 2006.[90] For this study, the IPO data were matched to metropolitan areas using the zip codes of the companies' headquarters. As many as 112 of 358 metropolitan areas were home to at least one company that went public between 2000 and 2006.

The figure below compares the average per capita value of IPOs, over the 2000 to 2006 period, for metropolitan areas with above and below average patents per capita over the preceding 1996–2000 period to allow time for patents to have an effect. Without inferring causality, those metropolitan areas with higher patent intensity witnessed IPO activity worth more than five times the per capita value. As the appendix discusses, the significant relationship remains after controlling for tech-sector employment shares, population, educational attainment, and output per worker.

Looking at either the value or number of IPOs across metropolitan areas, it is clear that patenting activity is highly correlated. Metro areas that patent more generate far more IPOs than those that do not. Table 8 sorts metros areas by those with the most value from IPOs from 2000 to 2006. Large patenting metros like San Jose, San Francisco, and Boston dominate the top five. Baltimore and Las Vegas are the only outliers in the top ten with few patents. Other metro areas with high patenting rates like San Diego, Seattle, and Austin also make the list.

Research universities, a scientifically-educated workforce, and collaboration play an important role in driving metropolitan innovation.

The evidence presented above is clear that patenting is strongly associated with national and regional economic performance. With so much at stake, it is worth analyzing why some metro areas patent so much more than others, and how others might boost invention. Four factors emerge as particularly

Figure 8. Average IPO Value per Capita for Metropolitan Areas with Above and Below Average Patents per Capita.

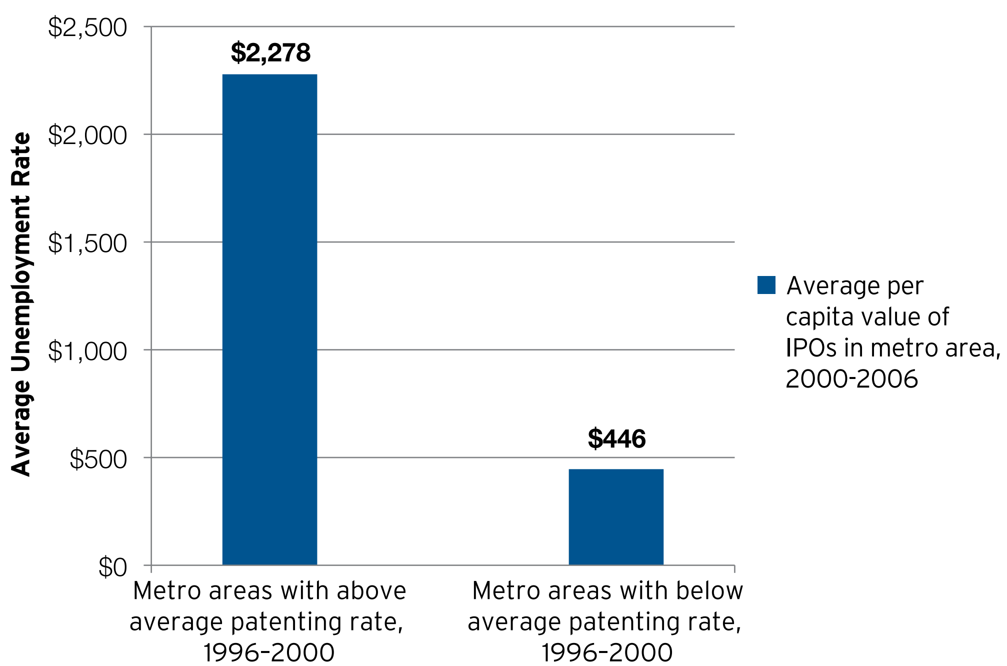


Table 8. Metro Areas with the Most Value from IPOs from 2000 to 2006 and the Number of Patents from 1996-2000

Metropolitan Area	Value of MSA IPOs, Mils	Number of IPOs	Largest IPO by value
San Jose-Sunnyvale-Santa Clara, CA	$84,264	89	Google Inc
New York-Northern New Jersey-Long Island, NY-NJ-PA	$64,074	72	Mastercard Inc
San Francisco-Oakland-Fremont, CA	$54,512	89	Webvan Group Inc*
Boston-Cambridge-Quincy, MA-NH	$30,676	54	Sycamore Networks Inc
Los Angeles-Long Beach-Santa Ana, CA	$27,135	42	Dreamworks Animation Inc
Washington-Arlington-Alexandria, DC-VA-MD-WV	$22,442	36	Kpmg Consulting Inc
Chicago-Joliet-Naperville, IL-IN-WI	$20,543	25	Cbot Holdings Inc
Baltimore-Towson, MD	$20,200	9	Corvis Corp
Las Vegas-Paradise, NV	$20,088	10	Las Vegas Sands Corp
San Diego-Carlsbad-San Marcos, CA	$19,570	36	Saic Inc
Dallas-Fort Worth-Arlington, TX	$16,450	21	Energy Transfer Equity Lp
Seattle-Tacoma-Bellevue, WA	$12,785	23	Onvia Com Inc
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	$12,521	22	Aramark Worldwide Corp
Houston-Sugar Land-Baytown, TX	$12,071	18	Complete Production Svcs Inc
Denver-Aurora-Broomfield, CO	$9,822	16	Regal Entertainment Group
Des Moines-West Des Moines, IA	$8,838	2	Principal Financial Group Inc
Minneapolis-St. Paul-Bloomington, MN-WI	$8,599	21	Lawson Software Inc
Atlanta-Sandy Springs-Marietta, GA	$8,125	17	United Parcel Service Inc
Bridgeport-Stamford-Norwalk, CT	$7,647	8	Priceline Com Inc
Austin-Round Rock-San Marcos, TX	$6,842	9	Silicon Laboratories Inc
Average for all metro areas	$23,360	31	

*Source: Brookings analysis of Strumsky patent database and IPO data from Martin Kenney and Donald Patton. 2010. Firm Database of Initial Public Offerings (IPOs) from June 1996 through 2006. (Version B). IPO data is reported in millions of 2011 dollars and refers to the 2000 to 2006 period. Patents refer to the 1996 to 2000 period. One patent is assigned to metro area if at least one inventor lives there. *This company turned out to be a rather high-profile failure, but such is the nature of innovation and entrepreneurship.*

strong predictors of patenting: tech-sector workforce, research universities, research collaboration, and college graduates with degrees in STEM fields, meaning science, computers, engineering, and mathematics related subjects.

Patenting is, of course, highly correlated with private-sector employment in patent-intensive industries. Three percent of the workforce is employed in the tech sector in the average metro area. From 2007 to 2011, 279 patents were invented in the average metro area with above average employment share in the tech sector, compared to just 20 in metros with below average employment. The fastest way to boost metro area patenting is to develop or attract large firms in high-patenting industries. The problem is that high-tech industries are defined as such, at least in part, because they patent more, and previous work has found that tax incentives and other fiscal inducements are much less important to more basic attributes like a skilled and flexible workforce, so the question is: What other factors can raise both patenting and high-tech employment?[91]

Access to university research institutions also seems to matter to both the rate of patenting and total level, and may also be important for firm attraction and development. A casual look at the data on which metros patent the most, brings to mind some of the nation's top research universities. San Jose has Stanford, Los Angeles has Cal Tech, San Francisco has Berkeley, Chicago has the University of Chicago, and Boston has MIT and Harvard. Yet, perhaps, large metro areas just happen to have major research universities, or industry success leads to funding for local research universities, as with Microsoft's support for the University of Washington.[92]

To examine this question in more detail, the analysis uses recent ranking from the National Research Council's (NRC) authoritative study on the quality of graduate research programs by institution across a large number of fields.[93] Programs were considered "top" ranked if they fell within the upper 90th percentile in their field, according to an average of the two most comprehensive summary rankings from the NRC, which give high weight to factors such as research grants won by faculty and quantitative GRE scores of students. The number of students was not considered in the present analysis.

The six metropolitan areas with the most patents all have at least 10 graduate level programs, and Detroit is the only metro in the top 10 on patenting that lacks access to top ranking science programs—since Ann Arbor, home of the University of Michigan, is not part of the Detroit metro area.

A more rigorous analysis reinforces the importance of institutions of science to patenting.[94] As Figure 7 shows, the 48 metro areas with at least one top-ranked science program patent at a higher rate than other metro areas. Yet, the data also show that second tier research programs also contribute to metro patenting. The 67 metro areas that do not have top-ranked science programs but do have lower ranked science programs still patent at a much higher rate than metros with no graduate programs in science. The results are similar for explaining the number of patents, rather than patents per capita. Surprisingly, the presence of national federal labs in a metropolitan area is not associated with more patenting, controlling for research programs, the tech sector employment share, science education attainment rates, and population size.[95]

Strong research universities seem to enhance metro areas invention beyond the mere presence of a tech sector. The positive and significant association between science programs and patenting remains after controlling for population and the share of employment in the tech sector, whether predicting the level of patents or the patenting rate (see Appendix Table 4 for details). The relationship between top science programs and patenting remains significance even if Boston, San Jose, and San Francisco are excluded. This analysis cannot rule out the possibility that universities become better as a result of corporate support from the tech sector.

Ranked by the presence of top science programs, the Boston metropolitan area dominates all others with 43 top science programs, thanks to Harvard and MIT. Yet, as Table 9 implies, California is the strongest state. It has 3 of the top 5 metro areas and 6 in the top 20, led by UC-Berkeley, Stanford,

Figure 9. Metro Patenting and Presence of University Graduate Programs in Science

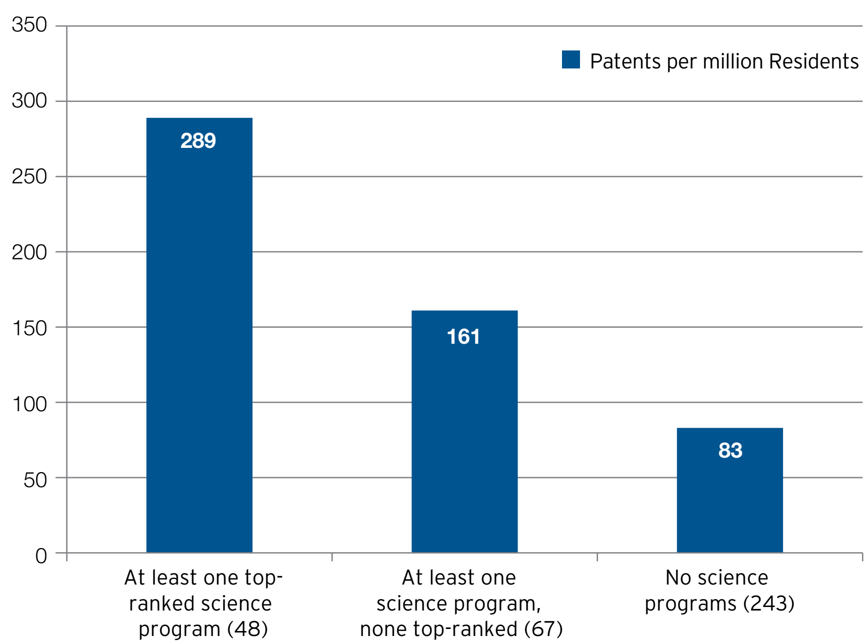


Table 9. Metro Areas with Top-Ranked Research Programs in Science Fields and Recent Patenting Rate

	Number of top-ranked science programs	Patents per million residents, 2007-2011	Institution with Most Top Programs
Boston-Cambridge-Quincy, MA-NH	43	874	Harvard University
San Francisco-Oakland-Fremont, CA	33	1,630	University of California-Berkeley
Los Angeles-Long Beach-Santa Ana, CA	30	423	California Institute of Technology
San Jose-Sunnyvale-Santa Clara, CA	24	5,035	Stanford University
New Haven-Milford, CT	15	590	Yale University
Trenton-Ewing, NJ	13	1,072	Princeton University
Ann Arbor, MI	12	1,690	University of Michigan-Ann Arbor
Durham-Chapel Hill, NC	11	838	University of North Carolina, Chapel Hill
Madison, WI	11	1,112	University of Wisconsin-Madison
Chicago-Joliet-Naperville, IL-IN-WI	10	408	University of Chicago
New York-Northern New Jersey-Long Island, NY-NJ-PA	10	365	Columbia University
Champaign-Urbana, IL	9	414	University of Illinois at Urbana-Champaign
State College, PA	9	597	Penn State University
San Diego-Carlsbad-San Marcos, CA	8	1,035	University of California-San Diego
Seattle-Tacoma-Bellevue, WA	8	1,165	University of Washington
Ithaca, NY	7	401	Cornell University
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	7	959	University of Pennsylvania
Santa Barbara-Santa Maria-Goleta, CA	7	652	University of California-Santa Barbara
Atlanta-Sandy Springs-Marietta, GA	6	283	Georgia Institute of Technology
Sacramento--Arden-Arcade--Roseville, CA	6	184	University of California-Davis

Source: Brookings analysis of National Research Council data on academic programs, Strumsky Patent Database, and Census Bureau. One patent is assigned to metro area if at least one inventor lives there.

and Cal-Tech and UCLA. Some of California's lesser known schools also contribute to the high ranking of San Diego, Santa Barbara, and Sacramento. Seattle makes the top 20 with the University of Washington. New York, Philadelphia, and other metros with Ivy League institutions make the list, including Trenton, New Haven, and Ithaca. The South is under-represented but includes the well-known Durham-Chapel Hill area, and Atlanta, with Georgia Tech. Four Big 10 schools anchor strong metro performance in Champaign-Urbana, State College, Ann Arbor, and Madison.

The uneven presence of top research universities helps explain the uneven distribution of patenting across metro areas. The 48 metro areas with high-ranking science doctoral programs account for the majority—62 percent—of all patents invented in metro areas from 2007 to 2011, though they have just 46 percent of the total metropolitan population, as of 2010. Another 25 percent of metro area patents are invented by researchers living in an area with at least one science program, though none in the top tier. Just 14 percent are invented by researchers living in metro areas with zero doctoral programs in science, though these areas are home to 27 percent of the total metropolitan population.

While research universities also produce STEM graduates, a metropolitan area's STEM bachelor's degree attainment rate also appears to have an independent effect on invention. A highly STEM educated workforce benefits existing tech firms and helps attract new ones. The average metropolitan area has a STEM degree attainment rate of just 8.5 percent, though it is above 20 percent in the metro areas of Ithaca, New York, Boulder, Colorado, Corvallis, Oregon, San Jose, Ames, Iowa, Ann Arbor Michigan, and Washington D.C. Just a five percentage point increase in the share of workers with a STEM bachelor's degree predicts an increase of 176 patents per million residents.

Another factor associated with high-patenting rates is the degree of collaboration. Metropolitan areas with more inventors per patent—a measure of research team size—patent at higher rates. In the average metropolitan areas, patents typically have three co-inventors. Increasing the average number of collaborators by one, predicts 87 extra patents per million residents, controlling for other variables.

Large metro areas like San Francisco, Cincinnati, Seattle, Albany, and San Diego recognize at least four inventors on the average patent granted from 2007 to 2011. A few smaller metro areas also have high collaboration rates and high innovation, rates like Poughkeepsie-Newburgh-Middletown, New York, Boulder, Colorado, Trenton, New Jersey (because Princeton is included). There are also a disproportionate number of high-collaboration metro areas in the Midwest, especially Wisconsin: Oshkosh-Neenah, Appleton, Racine, and Madison.

One reason why metro area team size varies is related to industry differences. The patent categories—like industries—with the largest average team sizes include chemistry technology, biotechnology, data processing, video distribution, computer software, nanotechnology, computer hardware, and resins. These more collaborative subcategories of patents are more likely to involve universities and the public sector. There is a very high correlation between the average team size of a patenting category and the share of patents owned by universities or funded by federal dollars. Another factor may be state "non-compete" regulations that sometimes prevent workers from putting their skills to work for competitors.[96]

Some readers may wonder if the results discussed above—particularly metropolitan changes in patenting—are driven by industry-patent orientations of metropolitan areas, rather than the underlying assets mentioned. In other words: Did San Jose become so innovative because it was lucky enough to be strong in technological classes that proved to be fast-growing over recent decades?

To test this idea, the change in the number of patents was calculated for each USPTO class from 1980 to 2010 (using 5-year moving averages in grant year to adjust for year-to-year anomalies). Semiconductor device manufacturing processes expanded the most. For that class, 4,772 more patents were granted in the 2010 period than the 1980 period. Various IT and communications technology patents were also at the top, though a few bio-tech classes were as well. The question is this: Did the expansion of these technologies nationally and globally account for the increase in metropolitan patenting for those places that already had a large share of these patents in 1980?

Not entirely. Metropolitan San Jose did have a large market share of the semiconductor processes patents in 1980 (roughly 7.6 percent of all grants came from inventors living there), but New York City had an even larger share, at 9.7. Yet, by 2010, New York's city's market share fell to 3.2 percent while San Jose's increased to 10.1 percent. Looking across all patent classes, it turns out that only 36 percent of San Jose's 2010 patents could be explained by the rise of patent classes, based on its 1980 market share. New York, on the other hand, had fewer patents in 2010 than expected, based on its 1980 market share.

To be more systematic, a regression analysis was performed to examine 1980 to 2010 changes in patenting while controlling for the patent class effect.[97] It turns out that the patent class effect is strongly significant, but so are the other variables mentioned, including the number of top science research programs (which had the highest statistical significance), tech sector employment shares, population, and bachelor's degree attainment (science bachelor's degree attainment was not available in 1980). In other words, the places that garnered extra market share in large patent classes—and therefore most took advantage of market trends—often had leading academic research programs in science fields and a large highly skilled workforce.

Patents funded by the U.S. government tend to be of especially high quality, and federal small business R&D funding is associated with significantly higher metropolitan productivity growth.

R&D is extremely important to innovation. To illustrate, consider that 66 percent of R&D-performing companies introduced a new or significantly improved product into the market between 2006 and 2008, compared to only 7 percent for companies that do not perform R&D.[98] Likewise, R&D performing companies are much more likely to rate patents as somewhat or very important to the company (41 percent) compared to non-R&D performing companies (3 percent).[99]

From the 1950s through the 1970s, most R&D funding in the United States was provided by the federal government. In the late 1970s, the share fell below half and now stood at slightly less than one third in 2009.[100] The primary rationale for public investment in R&D is that the resulting knowledge and innovations are partly public goods, meanings that the companies that discover new ideas or invent new technologies gain only a fraction of the social value. There is strong empirical evidence behind this theory, and economists estimate that levels of R&D are roughly one quarter of what they should be to optimize growth.[101] Moreover, the recent history of technology shows that the public sector has funded key developments across a wide range of important technologies, such as the internet, satellite communications, health treatments, and even hydraulic fracturing for natural gas (or fracking).[102]

Despite the massive public sector role in funding R&D, only a small portion of the funding—8 percent in 2009—is performed directly by government agency employees. Most of the money—over 60 percent in 2009—goes to private companies, but a substantial and growing share—about a third—goes to academia and federal research labs. In fact, roughly two-thirds of academic R&D has come from the public sector in recent years, with most from the federal government and a smaller portion from state and local sources. Along these lines, federal R&D is more likely to be used for basic research. In 2009, federal dollars made up 53 percent of basic research funding, but only 31 percent of total funding.[103] These facts explain why corporate R&D funding is much more likely to yield a patent than government research dollars. Since 2000, only 2 percent of patents have declared federal government funding in an average year, which is down only slightly from the 1980s.

Overall, in 2011, 91 percent of granted patents were invented by private corporations, 1 percent by individuals, 1 percent by the federal government, 2 percent by national labs, and 6 percent by universities (up from 1 percent in the 1970s). That same year, 4 percent of all patents reported funding from the federal government.

While the direct federal government role is small, federally financed patents of are of higher quality than those funded by industry. Government funded patents receive significantly more citations and claims, regardless of the patent owner, than other patents. Table 10 presents the data on claims. Universities stand out as having the largest number of claims per patent, a sign of broader intellectual property claims. However, this is partly because university researchers are more likely to receive government financing. Patents invented by workers at private companies contain 4.4 more claims per patent if sponsored by government funding, compared to those with no government funding. Individual researchers and national labs also invent patents with more claims if funded by the government.

The results are similar looking at patent citations within 8 years. Table 11 reports the results. Universities, again, are producing patents with the highest rate of citations, followed by private companies. Patents that receive public funding garner significantly more citations per patent, regardless of the affiliation of the inventors

Not all federal funding yields patents of the same quality, according to these measures. Funding from the Defense Department's Advanced Research Projects Agency (DARPA) garner the highest value patents, measured by claims per patent. DARPA sponsored patents are also cited much more frequently than private sector patents, with 8.8 citations per patent over an 8 year period. The National Science Foundation is second on claims but receives the highest number of citations per patent, at 9.1. The Department of Energy and EPA are roughly in the middle on claims, and score somewhat poorly on citations, compared to other programs. NASA does better on citations than claims. Overall, however, government funded patents from any source score at a higher rate of value than the average private company owned patent.

Other than government funding, patents with higher claims tend to have more collaborators. This

Table 10. Average Claims per Granted Patent by Assignee and Government Funding, 1975-2012 Applications

	Claims in average patent	Claims in average patent with government funding	Claims in average patent without government funding
Private Company	14.4	18.8	14.4
Individual	12.5	22.2	12.5
University	18.4	19.4	17.9
Government Agency	11.6	10.5	12.3
National Lab	14.9	18.4	14.2

Differences between those that receive and do not receive government funding are statistically significant, with p-values less than 0.00 and t-statistics above 10.

Table 11. Citations Within Eight Years per Granted Patent by Assignee and Government Funding, 1975–2012 Applications

	Citations of average patent	Citations of average patent with government funding	Citations of average patent without government funding
Private Company	6.9	8.3	6.9
Individual	5.7	9.9	5.7
University	8.0	8.6	7.7
Government Agency	4.9	5.0	4.8
National Lab	4.8	7.2	4.3

Differences between those that receive and do not receive government funding are statistically significant, with p-values less than 0.00 and t-statistics above 2.8.

is evident at the metropolitan scale, as Table 13 shows. The metropolitan areas with the most claims per patent—San Jose, Houston, San Diego, Washington D.C., and Albany—tend to have a high number of inventors per patent, and to a higher share of patents funded by the federal government. The ten metropolitan areas with the most claims per patent had average team sizes of 3.6, compared to 2.6 for those with the fewest claims per patent (e.g. McAllen, Cape Coral, Youngstown, and Bakersfield). Likewise, the share receiving federal funding is 3.1 percent for the top 10, compared to just 0.8 percent for the bottom 10. In Albuquerque, home to Sandia Laboratory and Air Force research labs, the federal share is particular high.

The foregoing data suggest that patents funded with federal R&D dollars tend to be more socially valuable than those funded with private dollars, but they do not shed light on whether or not a dollar of public investment yields a higher social return than a dollar of private investment. As mentioned, federal R&D spending tends to target more basic projects which are less likely to yield patents and commercial products. Yet, there is one large federal program that focuses on applied research and commercial development: the multi-agency Small Business Research program (SBIR).

This program, which gives out roughly $2 billion per year, lends itself more easily to a comparison with private sector efforts and has been well-studied. Projects that make it to a second phase of funding yields an average of 1.7 research publications and 0.6 patents for every grant, according to a comprehensive study.[104] With an average grant size of $656,000, this amounts to just over $1.1 million per patent and $0.4 million per scientific publication. By this standard, the program is actually more efficient than the private sector at creating patents, given that in recent years one patent has been granted to domestic inventors for every $3.4 million of total U.S. R&D spending. The SBIR average grantee earns more than twice as much in sales and licensing of technology than it receives in federal

Table 12. Claims and Citations per Patent by Government Agency Funding, 1975–2012 Applications

	Claims per patent	Citations within 8 years per patent
DARPA	22.0	8.8
NSF	21.9	9.1
ARMY	19.9	8.1
EPA	19.7	6.4
AIR FORCE	18.6	8.7
DOE	17.6	7.3
NIH	17.4	6.6
NASA	17.3	8.7
NAVY	16.5	7.8
Other Federal Funding	14.5	8.6

Table 13. Large Metropolitan Areas with the Most Claims per Patent, 2007-2011

	Claims per patent, 2007-2011	Inventors per patent, 2007-2011	Share of patents federally funded
Large metropolitan areas with most claims per patent			
Honolulu, HI	19.8	2.4	2.4%
San Jose-Sunnyvale-Santa Clara, CA	18.2	4.0	0.5%
Houston-Sugar Land-Baytown, TX	17.5	4.0	1.3%
Boise City-Nampa, ID	17.2	2.7	0.0%
Albuquerque, NM	16.9	3.3	17.7%
San Diego-Carlsbad-San Marcos, CA	16.4	4.3	2.3%
Washington-Arlington-Alexandria, DC-VA-MD-WV	16.2	3.6	2.2%
Buffalo-Niagara Falls, NY	16.1	4.0	1.5%
Tucson, AZ	16.1	3.8	1.4%
Albany-Schenectady-Troy, NY	15.8	4.4	1.7%
Average of top 10 MSAs	17.0	3.6	3.1%
Large metropolitan areas with fewest claims per patent			
Chattanooga, TN-GA	9.7	2.4	0.0%
Bakersfield-Delano, CA	9.4	2.4	0.5%
Little Rock-North Little Rock-Conway, AR	9.3	2.8	2.0%
Nashville-Davidson--Murfreesboro--Franklin, TN	9.3	3.5	2.3%
Miami-Fort Lauderdale-Pompano Beach, FL	8.5	2.6	0.6%
Modesto, CA	7.9	2.5	1.0%
Lakeland-Winter Haven, FL	7.7	3.4	0.2%
Youngstown-Warren-Boardman, OH-PA	7.5	2.7	0.0%
Cape Coral-Fort Myers, FL	6.3	1.4	0.0%
McAllen-Edinburg-Mission, TX	5.6	1.5	1.3%
Average of bottom 10 MSAs	8.1	2.5	0.8%
Average of all large MSAs	12.8	3.5	1.5%

Source: Brookings analysis of Strumsky Patent Database

funding, even as it attracts extra private sector funding. In all, SBIR seem to add roughly three times as much to the economy as it costs taxpayers in direct private economic benefits.[105]

Aside from patents, future sales, and the stimulation of investment, federal research dollars that support basic science and academic work have another hugely important effect on innovation through their fostering of scientific knowledge. In one recent survey of U.S. inventors who had filed patents in the United States, Japan, and Europe, 39 percent said that scientific and technical literature was an important or very important source of knowledge suggesting the research that led to their patent.[106] According to NSF data, just over 10 percent of U.S. patents actually cite academic publications.[107] Of course, there are many other potential technological (not to mention social) benefits to academic knowledge that never get translated into patents because they affect things that are hard to patent like theories, diagnoses, methods, and techniques.

With this in mind, the SBIR program's success at contributing to the scientific literature makes it look even more attractive. By contrast, researchers at corporations almost never publish in scientific journals, mostly because the valuable knowledge could immediately be adopted by competitors. Beyond SBIR, the federal role is quite large in fields like medicine and biotech. According to the database PubMed, there were over 100,286 journal articles funded with NIH money published in 2011 alone, which was the culmination of a rapid but steady increase in recent decades. To put that number in perspective, there were only about 800,000 English-language PubMed articles published in 2011 from any country, many of which received funding from non-U.S. governments.

Thus, it should be no surprise that metropolitan areas that receive more SBIR awards experience

Table 14. Metropolitan Areas with the Highest Number of Annual SBIR Awards, 2007-2011

	SBIR Awards	Millions of dollars in grant money per year
Boston-Cambridge-Quincy, MA-NH	676	$237
Los Angeles-Long Beach-Santa Ana, CA	424	$134
Washington-Arlington-Alexandria, DC-VA-MD-WV	378	$124
New York-Northern New Jersey-Long Island, NY-NJ-PA	221	$88
San Diego-Carlsbad-San Marcos, CA	192	$74
San Francisco-Oakland-Fremont, CA	181	$66
San Jose-Sunnyvale-Santa Clara, CA	161	$53
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	144	$54
Boulder, CO	122	$38
Huntsville, AL	101	$31
Chicago-Joliet-Naperville, IL-IN-WI	99	$31
Denver-Aurora-Broomfield, CO	98	$32
Dayton, OH	95	$27
Austin-Round Rock-San Marcos, TX	93	$30
Ann Arbor, MI	92	$36
Seattle-Tacoma-Bellevue, WA	91	$38
Baltimore-Towson, MD	81	$27
Minneapolis-St. Paul-Bloomington, MN-WI	71	$25
Atlanta-Sandy Springs-Marietta, GA	67	$22
Tucson, AZ	66	$20
Average for all metropolitan areas	16	$19

Source: Brookings analysis of SBIR program

higher productivity growth, even accounting for patents, tech-sector employment, population, education, and industry concentration, as was done earlier. The details of the analysis are shown in Appendix Table 5, and the main idea is that the amount of SBIR funding or the number of awards going to a metropolitan area in one year predicts faster productivity growth over the following ten years.

The 20 metropolitan areas that won the most SBIR awards from 2007 to 2011 are listed in Table 14. Large metro areas like Boston, Los Angeles, Washington, New York, and San Diego top the list. On a per worker basis, a different group of university-centered or lab-centered metropolitan areas are at the top, including Blacksburg, Virginia (Virginia Tech, Boulder, Colorado (the University of Colorado), Ithaca, New York (Cornell), Huntsville, Alabama—which has three Department of Defense labs—and Ann Arbor, Michigan.

The size of the SBIR effect is statistically and economically meaningful. The average grant in 2011 was just under half a million dollars, while the average effect on productivity was large enough to add roughly $3.3 million dollars to the regional economy. That represents a nearly seven fold return on investment on tax dollars, just for that region. The national and international benefits of the research are likely to be non-trivial as well. As with other aspects of the analysis in this report, these results could be biased by omitted variables or reverse causality, and so the precise causal effect remains unknown. Yet, the results here are consistent with other micro-level studies that avoid such problems.

Discussion and Policy Relevance

This report documents how a strong national innovation system plays out across a dispersed array of U.S. metropolitan areas, contributing to economic growth in both local places and across a large and diverse country.

Clear in these pages is the continued vibrancy of the U.S. innovation as well as the general utility of the nation's patenting system. Clear too is the centrality of geography to those systems, which depend on the intense matching, learning, and sharing that constantly goes on among people, institutions, and resources in urban regions. Along these lines, the paper at once affirms the general effectiveness of the U.S. invention system on most (though not all) fronts and documents that large metros constitute the critical sites of American innovative activity.

Above all, the report affirms the economic importance of invention and the continued dynamism of the U.S. invention system, even as the global economy becomes increasingly more competitive.

But the assessment should not license complacency. Just as these pages make clear the centrality of innovation to prosperity they underscore the increasing pace and competitiveness of invention. Patent ownership is more dispersed now than in previous decades going back to 1975, if not earlier; foreign inventors have never owned such a large share of USPTO patents, and given the elevated participation of developing countries, the global rate of invention has probably never been higher. This is born out in international comparisons: While still dominant in absolute numbers, the United States is ranked ninth on patents per capita, and just 13th on scientific research articles per capita.[108] Such trends argue that private firms, large and small, need to double down on their investments in R&D, invest in increasingly collaborative R&D models, and "ring-fence" those activities from the short-term pressures of Wall Street and quarterly reporting.

At other points, meanwhile, the paper makes clear the critical role that public policy plays in stoking, organizing, and accelerating innovative activity. In doing so, the report raises a number of questions about the nation's support of its universities, trends in R&D funding, the adequacy of U.S. education and training, and the integrity of the patent system. Likewise, the extreme variation of metros' inventive activity as measured by patenting rates underscores the fact that in many places the available mixes of people, resources, institutions, and industries in the United States remain massively sub-optimal.

And so the present analysis—which reports on the workings of a national innovation and patenting system that is at the same time intensely local—points to the need for a two-tiered, federalist approach to maintaining and maximizing the vitality of the U.S. system. Similarly, two general areas of effort come to the fore:

- The federal government should establish and maintain a sound platform for innovative activity
- Regions and their states must work foster innovative activity "bottom up"

On both fronts, it should be noted, the particular array of policy initiatives that will be relevant will vary sharply with the extreme variation of the conditions that exist in U.S. metropolitan areas, where innovation metros like Boston, San Jose, and San Francisco race to maintain their world-leading edge even as metros like McAllen and Modesto—with no research universities, meager levels of human capital in STEM fields, and few technology forms—struggle to assemble the least purchase in the innovation game. No one policy or approach will suffice across such a diverse set of local innovation systems.

Federal platform-setting

The federal role in promoting innovation is foundational. All jurisdictions—national, state, and local—have an interest in maximizing innovation. After all, the material well-being of all places now hinges on the continuous creation of new ideas, new technologies, and new products—and must be maximized. However, the federal government—like all other national governments in the world—will always have a special role in fostering innovation given the presence of pervasive, far-reaching market failures including externalities, network failures, system interdependencies, and the public-goods and border-crossing nature of technology platforms.[109] These broad-ranging complications of innovative activity always and everywhere threaten to depress the level of the innovation. Accordingly, the federal government retains a crucial role in responding to those problems and in doing so setting a stable and adequate platform for innovative activity in the nation's industries and metropolitan regions.

The evidence that federal R&D spending is worthy of public support is abundant. In addition to the findings introduced above, economists have carefully studied R&D programs like SBIR.[110] In the 1990s, the SBIR portfolio was roughly equal in size to the private sector venture capital market, and at various points in the program's history, firms like Apple, Compaq, Intel, and Federal Express received grants.[111] Including the Small Business Technology Transfer Program (STTR), from 1997 to 2011, $26 billion was given out to fund nearly 100,000 projects.[112] Studies have shown that grantees from these programs attracted subsequent private sector investments and tend to outperform their peers on economic performance measures.[113]

Along those lines, it has become increasingly clear that the nation—to maintain its leadership in the inventiveness that drives economic growth—must consistently work on at least three fronts to: invest in the maintenance of a robust U.S. research enterprise; help ensure the existence of an adequate supply of skilled workers; and safeguard the integrity of the patent system.

A first priority of federal platform-setting must be to **invest in a robust research enterprise** in the United States. Copious amounts of basic and applied research remain a critical foundation for innovation, invention, and prosperity. Or as pronounced the landmark 2005 . National Academy of Science report *Rising Above the Gathering Storm,* "A balanced research portfolio in all fields of science and engineering research is critical to U.S. prosperity."[114] Which is why the federal government—recognizing the public good nature of research—has traditionally supported both basic and applied scientific and engineering research, both through grants to universities and via subsidies to companies and private inventors.

And yet, in recent decades the federal commitment to funding such activities has seemed to waver. Overall federal R&D investments grew in constant dollars by just 2.1 percent per year each year from 1980 to 2009—lower than the rate of GDP growth over that period (2.7 percent) and lower than federal R&D spending growth between 1953 and 1980 (5.4 percent). Looking more specifically at academic and corporate accounts the story persists. The rate of growth in federal spending on academic R&D has gradually declined from the 1970s through the 1990s. If not for the 2009 American Recovery and Reinvestment Act (ARRA or the Recovery Act), the 2000s would have represented the slowest decade of federal academic R&D spending since data have been reported. ARRA gave a 19 percent boost in federal academic R&D spending over congressional obligations. The problem is that ARRA programs are temporary so without legislative action, federal R&D spending growth will dip substantially, potentially depressing economic growth in future decades. Given the enormous importance of academic research to innovation, it is essential to maintain its growth.[115]

At the same time, support of the nation's most important incentive for private-sector R&D activity—the Research and Experimentation (R&E) Tax Credit (usually called the "R&D tax credit)—has also dwindled. Established in 1981, the credit was the world's first and provided companies large and small with a powerful added incentive for R&D investment given the fact firms often cannot fully capture the returns on their investments due to spillover effects.[116] However, over time, the credit has become less generous and predictable relative to what other countries provide. As a result, the Information Technology and Innovation Foundation (ITIF) recently concluded that the United States now ranks 27th in the world in terms of R&D tax incentive generosity.[117] At the same time, uncertainty about the availability and level of the U.S. credit due to repeated expirations and reauthorizations may well have undercut long-term planning and overall R&D investments.

And so the federal agenda for maintaining and increasing the robustness of the U.S. research enterprise must include new investments in the adequacy, stability, and effectiveness of the nation's research platform. To start with, the nation must reassert its world leadership on research investment by supporting with appropriations, even in the context of deficit reduction, President Obama's goal that total U.S. R&D expenditures reach and sustain a level of 3 percent of GDP—which is just above the historic high of 2.9 percent, achieved in 1964.[118] At the same time, Congress needs to strengthen the R&E Tax Credit and make it permanent.[119] An increase of the rate of the Alternative Simplified

Table 15. Annual Growth Rate in Federal Obligations for Academic R&D by Decade

Decade	Annual Growth Rate
1970-1979	4.3%
1980-1989	3.8%
1990-1999	3.5%
2000-2009, without ARRA	2.7%
2000-2009, with ARRA	4.7%

Source: Brookings analysis of National Science Foundation data

Credit from its most recent level of 14 percent to 20 percent—combined with simplifications to ease the credit's use—would go a long way toward re-stimulating private-sector innovative activity as the nation's economy recovers from the Great Recession.

Finally, in bolstering the robustness of the U.S. research enterprise the federal government should maintain and step up its recent experiments with the creation of new formats and institutions for the acceleration of innovative activity. In this respect, with the innovation game increasingly complex, collaborative, and fast-moving getting the scale of the needed investment levels right is only part of the need. Implementing more and better models for inciting more effective translational, collaborative, and purpose-driven research matters just as much.[120] All of which argues for the nation to *step up federal support of promising new collaborative innovation models* including: various "grand challenge" research institutes (such as the Department of Energy's Energy Innovation Hubs or the proposed National Network of Manufacturing Innovation); proof-of-concept centers and new region-based translational platforms like the Department of Commerce's i6 Green and Jobs and Innovation Accelerator challenges; the government's several regional innovation cluster programs; and various longer-standing programs like the NSF's Engineering Research Centers and Industry/University Cooperative Research Center Program and the National Institute of Standards and Technology (NIST)'s Technology Innovation Program and Manufacturing Extension Partnership.[121] The creation and sustained support of more of these focused, multi-disciplinary, and collaborative technology development platforms will be crucial to ensuring that the nation extracts the most usable innovation out of its investments by inciting research that transcends stovepipes and sectoral divides, links academia to industry, and works on compelling problems. Making sure that these mechanisms take on a strong regional flavor and encourage "bottom up" activity will maximize the value of these efforts.

Equally important to securing a competitive platform for the next era of U.S. innovative activity is the imperative to **ensure the existence of an abundant supply of skilled workers**. Quite simply, the strength of the U.S. innovation system absolutely depends on the skills and ideas of the nation's workforce. Highly trained scientists or technicians are essential to conduct the research and implement the technologies needed to drive innovative companies and perform product and process development. Likewise, education is closely linked to entrepreneurship. According to one recent survey, 94 percent of U.S. patent inventors—with inventions between 2000 and 2003—hold a university degree, including 45 percent with a PhD. Of those, 95 percent of their highest degrees were in STEM fields, including over half in engineering.[122] Given this, it has been critical that for generations the United States constantly amassed the world's strongest cadre of highly-skilled scientists, engineers, and technology workers, both by educating and motivating top students here in the United States and by attracting the best and brightest from abroad.[123]

And yet, there is a problem: Notwithstanding the nation's history of educational achievement, U.S. educational attainment—especially in critical science, technology, engineering, and mathematics (STEM) domains—now lags that of many other nations. Only a small slice of the U.S. population is academically prepared to engage in the innovative scientific or technical research that leads to patents. Out of 34 developed countries, the United States ranks just 24th STEM graduates with a Bachelor's degree (equivalent) or higher as a share of the population aged 20 to 24 (see Table 16). Only 28 percent of U.S. degrees are being issued in STEM fields, compared to over 50 percent in many developed countries. At the heart of the challenge for the United States is the immense gap in outcomes between U.S. institutions of higher learning and its primary and secondary schools. Fifteen year-old students in the United States score lower on science and math exams than 23 other developed countries. At the other end, according to the Leiden Ranking (from Leiden University in the Netherlands), all ten of the top universities in the world are in the United States and 43 of the top 50.[124] Yet, at the elementary and secondary level international comparisons of U.S. students' on science and mathematics consistently place the United States much further down—as low as 23rd among OECD countries.[125] In addition, large interest-level and achievement gaps that exist among multiple groups, with African Americans, Hispanics, Native Americans, and women seriously underrepresented in many STEM fields. At the same time, admission slots to top universities are increasingly taken up by children from affluent families, as the locally controlled K-12 system increasingly allocates quality education to children based on their parent's ability to afford high housing costs.[126] Meanwhile, President's Council of Advisors on Science and Technology (PCAST) recently projected the need for producing, over the next decade, approximately 1

Table 16. Science Education Statistics for 2009, by Country

	STEM Tertiary Degree Graduates as Share of Population aged 20-24	Share of Tertiary Graduates in STEM Fields	Ranking of Universities by Average Quality of Institutions	Ranking of 15-year old student Test Scores on Math and Science
Finland	9%	58%	16	1
Korea	7%	59%	27	2
Slovak Republic	7%	37%	-	25
Czech Republic	6%	43%	33	20
United Kingdom	6%	41%	5	13
Poland	6%	27%	34	14
Portugal	6%	44%	21	26
Ireland	5%	37%	8	18
New Zealand	5%	37%	18	5
Iceland	5%	29%	-	16
Australia	5%	31%	13	8
France	5%	47%	15	19
Germany	5%	55%	14	10
Denmark	5%	32%	3	15
Sweden	4%	48%	7	24
Switzerland	4%	40%	1	6
Austria	4%	49%	12	22
Canada	4%	41%	11	4
Spain	4%	42%	22	28
Israel	4%	36%	17	31
Norway	4%	29%	10	17
Greece	3%	50%	24	30
Belgium	3%	37%	9	11
United States	3%	28%	4	23
Netherlands	3%	24%	2	7
Slovenia	3%	34%	31	12
Hungary	3%	31%	30	21
Estonia	3%	41%	-	9
Italy	3%	38%	20	29
Japan	2%	24%	28	3
Mexico	2%	50%	38	34
Turkey	2%	28%	35	32
Chile	1%	25%	32	33
Luxembourg	1%	53%	-	27

Source: Educational attainment based on Brookings analysis of OECD other data; Data are for 2009; University rankings calculated from Centre for Science and Technology Studies, Leiden University, The Netherlands and based on average number of citations of academic publications in science fields. 15 year old test scores are based on average of Program for International Student Assessment (PISA) scores for math and science; rankings are only among the countries listed.

million more college graduates in STEM fields than is expected under current assumptions.[127] The bottom line: The United States needs to provide more egalitarian educational opportunities in order to create a larger and better-trained technological workforce; otherwise its innovation system will crumble.

It is absolutely critical, then, that the United States move to increase the supply and quality of the U.S. STEM workforce. So what is the federal role in bolstering the nation's STEM workforce? PCAST confirms the need for the nation to redouble its effort on three fronts: K-12 STEM education, university STEM education, and recruitment of highly-skilled foreign workers.

The project should begin with efforts to *improve K-12 math and science education.* This task is a prerequisite for renewing the U.S. innovation system and improving the distribution of its economic gains and it will be gargantuan. Fortunately, however, numerous reports by PCAST and other authorities detail significant consensus about the sort of action steps required.[128] At the broadest level, most observers suggest the federal government should vigorously support the current state-led effort to develop common standards in STEM subjects and invest in programs designed to produce specifically trained middle- and high-school STEM teachers and recognize the best of them as STEM master teachers. Likewise, many analysts underscore the need to inspire students' interest in STEM subjects through individual and group experiences outside the classroom and through more immersive, in-depth, courses oriented to more active learning. To that end PCAST and others call for the federal government help fund new federal, state, or local programs to provide high-quality after- and outside-school or extended day STEM experiences (such as STEM contests, fabrication laboratories, company visits, summer and afterschool programs, and so on). Finally, numerous experts call for the federal government to actively promote the establishment of hundreds of new STEM-focused schools. PCAST calls for the federal government to help create at least 200 highly-STEM-focused high schools and 800 STEM elementary and middle schools while ITIF calls for Congress to fund the Department of Education to create 400 new specialty STEM high schools.

Once students are inspired and prepared, meanwhile, they must be engaged to excel. For that reason, work to *improve undergraduate STEM education,* especially during the first two years of college, will also be crucial to bolstering the nation's STEM workforce. This engagement process must begin with a continued commitment to maintaining Pell Grants and other federal supports for higher education since improving STEM education at the K-12 level and moving more young people into the STEM pipeline will be futile if college is unaffordable or out-of-reach. But beyond that, new efforts must be launched to entice more undergrads into STEM courses and then into STEM majors in their first two years of higher education. Washington has a role to play at this by helping to catalyze and finance the development, dissemination, and wide adoption of empirically validated college STEM teaching practices, including the replacement of standard laboratory course with more discovery-based research courses.[129]

Yet even positing outstanding progress in the next decade of producing a more robust cadre of home-grown researchers, technologists, and technical workers the nation will continue to need to *attract and retain significant numbers of the world's best researchers and students from abroad.*[130] Immigrants have long played a crucial role in the U.S. innovation system. Such foreign-born citizens and visitors represent fully 24 percent of the nation's scientists and 47 percent of U.S. engineers with doctorate degrees. Moreover, their numbers encompass one-quarter of the founders of U.S. public companies that were venture capital-backed.[131] And so the United States must continue to draw the best science and engineering talent from foreign countries even as more nations compete to attract such students and workers and as more of them elect to seek opportunity at home. One possible strategy: Expand the number of high-skilled foreign workers that may be employed by U.S. companies as one element of a comprehensive immigration reform. Two mechanisms for this would be to: Allow foreign students that receive a graduate STEM degree from a U.S. university to receive a green card (which would also cover his or her spouse and children) and to increase the number of H-1B visas. Such provisions will not only add to the nation's stock of talent but ensure that the nation's STEM workforce remains diverse and internationally linked—an important consideration given the international and cross-cultural collaborations that increasingly define the nation's inventive activity.

Finally, the platform-setting responsibility of the federal government requires that Washington **safeguard the integrity and efficiency of the patent system.** In this regard, while the patent system does not seem to be fundamentally broken in the way some scholars contend, few would say the system is optimally designed and operated—and it does appear vulnerable to abusive litigation.

Most simply, there is the problem of funding and staffing the patent office adequately enough to keep pace with the tremendous increase in patent applications and the increasing complexity of technology. Between 1975 and 1979, it took an average of 1.9 years for a patent application to be granted, but from 2007–2011, that pendency period increased to 3.2 years. This is recognized by the patent office and examiner staffing has recently increased with the goal of reducing pendency and improving the quality of examination.[132] Yet, the issue will need to be constantly revisited. The situation was elegantly stated by the head of the patent office in a report to congress—in 1886:

> "The field of invention is widening so rapidly and the distinctions which are constantly required to be made have become so nice in many instances that the greatest care and skill are required to determine accurately what is new and what is old. Each year the history of invention becomes more elaborate and complicated and no department of the Government more needs the services of men who are not only learned in the sciences but who have become familiar by constant association month by month and year by year with the histories written and unwritten of invention and the arts."[133]

The need is just as great today.

A more troubling aspect of the patent system is the role of non-practicing entities (NPEs): the so-called "troll" entities that are buying up patent portfolios with the sole purpose of extracting payments from productive companies through negotiation or litigation. Since NPEs are not producers, their revenue comes solely (or mostly) from the licensing and litigation of intellectual property, which gives them a strong incentive to issue legal challenges, while avoiding reputational repercussions from consumers. Not surprisingly, a raft of academic and journalistic accounts is increasingly suggesting that non-producers (along with spurious or hyper-strategic) patent suits are perverting the patenting system. Action is required.

A complete prohibition of NPEs' ability to bring up patent litigation disputes would go too far, however. Throughout U.S. history, patents have been monetized, providing an important spark to innovation.[134] In so far as small businesses cannot afford a legal defense staff to monitor possible value-diminishing infringements, NPEs can serve a useful function by increasing the value of inventions and minimizing infringement risk.[135] Yet, *parties that bring frivolous law suits against companies for the sole purpose of extracting money should be punished.* One proposal, introduced by Rep. Peter DeFazio (D-OR) would force the litigant to pay the full legal costs of the alleged infringer if the judge decides that there was no reasonable likelihood of success.[136] While attractive in spirit, the legislation would limit this provision to computer hardware and software patents, and there would be tremendous uncertainty as to whether or not an NPE claim would be deemed frivolous. For his part, Judge Richard Posner has proposed that assignees should lose their patent if they do not employ it in a product within a specified time period.[137] Such a reform has merit on the surface but it would substantially limit the ability of inventors to monetize their work. For these reasons, legislation should allow NPEs to defend patent rights like other owners, while still recognizing their uniquely perverse incentives to litigate.

This all points to an alternative proposal. NPEs should be prohibited from initiating litigation or legal threats of any kind related to a patent claim until their claim has first been assessed and approved as valid by a patent authority, such as the Patent Trial and Review Board. An expert judge could be charged with assessing the merits of the infringement claim, on a preliminary and ex-parte only basis (meaning between the owner and the judge), and whether or not the owner can proceed with legal action (without taking a view as to whether or not the owner should win redress). This review would largely free productive non-infringing companies from having to respond to egregious claims made by NPEs, and it would only compel them to settle or make their case in court after an initial screen. NPEs that pursued threatening action without acquiring the needed pre-approval would have to pay steep fines to the U.S. patent office and to the company it harassed and would forfeit ownership of the patent in question, which would go to the public domain. To insure that this system is not flooded with a huge case load from NPEs, moreover, the judge would also have the power to refer the patent back to the USPTO for re-examination, including the possible rejection and refinement of claims. For the purposes of such legislation, NPEs subject to this regulation could be deemed "patent monetization entities" and defined in the following manner: *Patent owning for-profit businesses that do not earn the majority of their revenue through the sale of products supported by patents and have no plans to do so within two years.*[138] This definition would exclude universities, government labs, tech companies, and start-ups, which could prove their intention to shift revenue to the sale of patented products by submitting formal plans used to raise capital.[139] Details would have to be sorted out by patent law experts, but these reforms, or others like them, could very well end the troll problem, while preserving the market for patents and the integrity of the patent system.

Regional and state leadership

And yet, while many innovation dynamics are national and boundary crossing and so require federal nurturing, the fact remains that the innovation process turns out to be intensely localized.

More than traditional industries, the innovation economy has an inherent tendency toward geographical clustering. In keeping with that, this report has demonstrated the intense concentration of U.S. innovative activity not just in U.S. metropolitan areas but in a relatively narrow sub-set of those metros. There, in places like Boston or San Jose, the presence of strong research universities, a scientifically educated workforce, and innovative industries is driving intense patenting activity and strong economic performance even as the absence of those factors in other metros (like McAllen, Las Vegas, or New Orleans) leaves them lagging. All of which suggests the critical role and compelling interest the nation's metropolitan areas and their states have in attending to the regional underpinnings of the U.S. innovation economy. Positioned close to the institutions, firms, and people whose interactions drive invention, U.S. regions and their states possess critical leverage in convening, aligning, and supporting the relevant local actors so as to maximize the economic yield of their exchanges.

Accordingly, all metropolitan and state leaders have the means and positioning to enhance U.S. innovative activity from the "bottom up." A crucial catalyzing role that regional and state leaders must play is to **promote, convene, and inform local efforts to understand and bolster the regional innovation system and track performance.** Work to *employ the bully pulpit* to talk up the importance of innovation and regional and state economic development can incite action and engage disparate actors.[140] Moreover, such signaling can help *convene regional actors* and catalyze the critical collaborative exchanges among the regional businesses, industry associations, universities, governments, and other entities that comprise the local innovation system. For example, regions such as New York, Northeast Ohio, and Seattle and states as diverse as Colorado, Nevada, New York, and Tennessee are currently advancing concerted efforts to highlight the centrality of regional innovation systems and to call forth regional innovation cluster activities to intensify their action.[141] In this connection, intent regions and states should move aggressively to use data and analysis to objectively assess the strengths and weaknesses, competitive prospects, and specific needs of local innovation systems.[142]

Regions and especially states, informed by strong analytics, may also need to **target resources to address discrete gaps in regional innovation systems' performance**. In this respect, metropolitan and state interventions should be pursued judiciously to focus on attacking specific system barriers to inventiveness. That means they need to: support top-quality knowledge infrastructure, both at the university and K-12 level; mitigate market failures in finance, speed knowledge transfer; promote its commercialization; and work to attend to enhance the flow of inventive exchange in regional innovation clusters.

To give a few concrete examples, the Entrepreneurial Development Center, an "accelerator" in Des Moines, Iowa helps local start-ups get funding and commercialize by providing something like a social network for inventors, investors, and entrepreneurs.[143] Another organization there provides start-up funding, using private and public dollars.[144] At the state level, governments outside of Massachusetts and California can bolster relatively thin lending markets by augmenting private sector financing without eliminating risk. The Small Business Jobs Act of 2010 allowed the Treasury Department to spend approximately $1.5 billion to support state lending policies—like venture capital funds—worth an estimated $15 billion. As of early 2012, 47 states were participating in this program, called the State Small Business Credit Initiative.[145]

Investments to *construct and maintain topflight knowledge infrastructure,* including strong education and training systems, loom large. This report has documented the critical role of universities and a well-trained STEM workforce in inventive activity. Therefore, strategic investments in universities' top science and technology programs; STEM-related education at all levels; and workforce training all amount to foundational support for the innovation process. Yet in this connection, these investments must be accompanied by constant nudges toward institutional innovation—new ways of developing R&D preeminence (as through business partnerships and targeted "star scholar" initiatives); new industry-oriented STEM training models; new STEM education options, such as "STEM high schools" and career and technical education. The same experimentation must also be brought to bear as regions and states work together to spur innovation more directly. With the economy increasingly dependent on innovation and higher education central to it many regions and states moved assertively to construct more strategic focused innovation capacity. Mayors and governors have invested directly in specific R&D initiatives; matched federal research funding in areas important to regional business development; or even created large, multi-year "innovation" funds to underwrite research in targeted areas fundamental to a region's economic development. Likewise, they have established a wide range of institutions and entities (research parks, centers of excellence, applied research hubs) aimed at linking higher education to regional innovation goals and industry. Such programs can be helpful in many regions, especially those with serious demonstrable gaps in their university research base. But what will be equally and perhaps more catalytic in regions with sound existing research activities will be moves to *speed knowledge transfer out of universities and into the regional private economy* through targeted programs that seek to actively reveal new intellectual property; streamline its marketing and licensing; and systematically incentivize universities to maximize outward knowledge flow.[146] In all of this much more information, reporting, transparency, and accountability is needed and will likely need to be incentivized by states.[147] Also needed in many regions are mechanisms to *accelerate the commercialization of intellectual property,* particularly through improvements in new firms' access to risk capital. Such access to capital is frequently spotty, given the geographical concentration of private seed and venture capital sources and the numerous risks that investors face. For that reason, regions and states can improve the availability of early stage capital in their innovation reasons by starting their own funding programs, launching prize competitions, investing their own money, or taking steps to encourage "angel" investments. Programs that make available modest grants for IP discovery, proof-of-concept development, and early commercialization work are proliferating and in many regions address a critical need.

Yet more action may be required: Regions and their states frequently need to take steps to **intensify the workings of regional innovation clusters**. Strong regional clusters—characterized by strong social interactions and dynamic knowledge spillovers—have been shown to foster and accelerate innovation and entrepreneurship.[148] Yet for numerous reasons the knowledge exchanges within a particular cluster in a particular region may occur at sub-optimal levels. Habits, location, institutional barriers: All of these may mean that researchers and firms with similar interests may exist near each other but have little formal interaction. And so regions or states—working with relevant regional scholarly, professional, and business organizations—may seek to intensify the level of knowledge exchange in the region. Leaders and organizations may *convene or help to better organize relevant knowledge and industry networks.* Such networks may facilitate work to *identify institutional or resource deficiencies and design responses.* And beyond that, cities, regional development organizations, or states may want to *provide small matching grants to help support and expand cluster capacity and initiatives*.[149] Through such grants cities, regional organizations, and states can help regional knowledge networks cohere, connect with industry, and begin to collaborate on innovation problems of shared interest. For their part, some cities are even beginning to delineate neighborhood-scale "innovation districts" to facilitate innovation through place-based city-making approaches.[150]

Finally, regions and states need to **link and align their existing policies, programs, and initiatives in service of their regional innovation strategies.** Direct, targeted and discrete new "innovation" initiatives clearly have a role in accelerating innovation. Institutional innovation will be critical going forward. However, significant impact can also come if cities, regions, and states *better organize existing programs*. Whether it be higher-ed planning and workforce training delivery, manufacturing or place-making policy, existing innovation-relevant programs should be aligned to advance the overall innovation project. Are educational programs cultivating a sense of discovery along with STEM facility? Does tax policy encourage or discourage inventive activity? Do available grant programs add up to a system for supporting discovery and commercialization or are they simply isolated programs? What about land-use and urban development policies? Are these creating dense environments for knowledge exchange or dismantling them? Such are the sort of questions that require serious consideration as regional and state leaders seek to tune their myriad existing activities to the innovation project. Which is to say: Like cluster development, innovation strategy is less a specific program than a framework through which to shape and coordinate the full range of local and state action.

* * *

Despite the Great Recession, the intensity of invention in the United States is high compared to both the rest of the world and its own history—propelling the growth and development the nation's great metropolitan areas. High quality inventions across a number of industries are transforming regions and creating spectacular wealth. Yet, many areas lack these assets and suffer as their less inventive firms stagnate or fail to generate high-paying jobs. Rather than looking to the consumer-driven inducements of entertainment, tourism, and retail to revive growth, regions and their states can turn their investments to more valuable and sustainable efforts to promote prosperity. The inventive capacity of regions is noticeably strengthened through educational attainment in STEM fields, academic training and research, collaboration, and public sector investments in basic and applied R&D. Each region will have to craft its own strategy to the specific shortcomings it faces. Given the growing size and geographic diversity of global markets, the rewards for successful invention have never been greater. If living standards in the United States are to progress at historic rates, the effort must rise to the occasion.

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84. See discussion in introduction and Duranton and Hubert, "Is the Division of Labour Limited by the Extent of the Market? ".

85. Productivity growth, as measured by GDP per worker from 1977 to 2012, was an astounding 5.3 percent each year for this sector, compared to 1.4 percent in each for the U.S. economy. In one of its component industries, the computer and electronics industry, productivity growth was an astronomical 23 percent per year from 1977 to 2012.

86. The bachelor's degree attainment rate is significant at 5 percent levels if tech sector employment is dropped from the regression, and vice versa. These variables are highly correlated, and multicollinearity can mask significant associations, though it does not bias the regression. As noted, the interaction of these terms is highly significant when included.

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94. Both patents per capita and the number of patents are considered to account for the non-linear relationship between programs and patents.

95. Indeed, there is a negative correlation between the number of labs and both patent outcome measures. Perhaps labs draw scientists away from the private sector where they are more productive, in terms of patenting. Data from National Science Foundation, available http://www.nsf.gov/statistics/ffrdclist/ (2011).

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98. National Science Foundation/Division of Science Resources Statistics, Business R&D and Innovation Survey, 2008.

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104. Charles W. Wessner, ed., Committee on Capitalizing on Science, Technology, and Innovation, National Research Council, An Assessment of the SBIR Program (Washington: The National Academies Press, 2008).

105. Brookings analysis of NRC survey data for Phase II SBIR awards from Wessner, Assessment of the SBIR Program. Average sales and additional private investment were counted as benefits and average award costs were counted as costs. The benefits were three times larger for the average award and exclude the social value of patents and research publications. Each award generated an average of 0.6 patents and 1.7 academic publications.

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